HYGIENE

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BY

J. LANE NOTTER, M.A., M.D.

CHAIRMAN OF COUNCIL AND EXAMINER TO THE ROYAL SANITARY INSTITUTE
EXAMINER IN PUBLIC HEALTH TO THE UNIVERSITIES OF CAMBRIDGE, MANCHESTER, AND LIVERPOOL
HON. MEMBER OF THE HUNGARIAN SOCIETY OF PUBLIC HEALTH, ETC.

AND

R. H. FIRTH

LIEUT.-COLONEL, ROYAL ARMY MEDICAL CORPS
PROFESSOR OF HYGIENE IN THE ROYAL ARMY MEDICAL COLLEGE
MEMBER OF COUNCIL AND EXAMINER TO THE ROYAL SANITARY INSTITUTE

SIXTH EDITION

LONGMANS, GREEN, AND CO.
39 PATERNOSTER ROW, LONDON
NEW YORK AND BOMBAY
1905

PREFACE TO THE SIXTH EDITION

RECOGNIZING and fully appreciating the favourable reception which has been accorded to previous editions of this small book, a formal preface to this new edition is perhaps hardly necessary. But, in view of the fact that the present issue has been completely revised, in many places completely rewritten and much new matter added, a few words of introduction are desirable. We have deemed it necessary to broaden somewhat the general plan of the book, in order to meet the needs of a wider circle of readers, and to keep abreast of the requirements of modern schemes of examination. This has been particularly the case in the chapters dealing with water examination, foods and dietetics, and the infective diseases, wherein an attempt has been made to bring the subject-matter well abreast of the times, and to summarize the essential facts regarding both the bacteriological examination of water supplies and the difficult subject of immunity to disease. No claim is made to have discussed these topics exhaustively; such is quite impossible in an elementary book of this kind, but we hope that sufficient information has been given to enable the student to acquire a working appreciation of the elementary facts and principles upon which, by a further study of more elaborate works, he can build up a more complete knowledge of the subjects.

In its new form, we hope that this book will be found to have retained its value as a plain and simple account of the great subject of Hygiene, as much for the general reader as for the science and medical student. For permission to copy and use certain illustrations we are indebted to the kindness of Mr. Bowley Bennett, Dr. Robertson, Dr. Porter, and Messrs. Jennings and Shanks.

September, 1905.

PREFACE TO THE FIFTH EDITION

THE continued demand for this manual has necessitated a new issue. In the preparation of this edition we have made no changes in the general plan of the work, but merely revised all chapters and endeavoured to bring each up to date, without unduly increasing the size of the volume.

May, 1902.

PREFACE TO THE FOURTH EDITION

THE favourable reception awarded to previous editions of this small book has necessitated the issue of a new edition. Without presuming to think that there does not still exist some room for improvement, we hope some progress has been effected by the revision which has been carried out. Whenever it has appeared desirable, new matter has been added by the introduction of such facts as were absolutely necessary, while no material changes have been made in the subject-matter.

WEST CLIFF, WOOLSTON, HANTS,
January, 1900.

PREFACE TO THE THIRD EDITION

THE rapid sale of the last edition of this book has suggested the preparation of a new issue. In this edition, beyond the correction of a few errors, previously overlooked, and the introduction of such facts as were absolutely necessary to bring the book up to date, no material changes have been made in the subject-matter.

WOOLSTON, HANTS,
1897.

PREFACE TO THE SECOND EDITION

THE favourable reception awarded to the first edition of this small book has necessitated the issue of a second within a year. Without presuming to think that there does not exist still some room for improvement, we hope that much progress has been effected in that direction by the revision which has been carried out. Wherever it has appeared necessary, the wording has been changed in order to render the meaning clearer, various modifications have been introduced, and a considerable amount of new matter added; notably, attention may be directed to the last chapter, which is devoted to sanitary legislation. In a work of this professedly elementary nature, we felt it would be impossible to adequately discuss the whole of sanitary law, but we have endeavoured to explain as simply as possible such subjects as appear to be requisite to be known by the head of every household.

We desire to avail ourselves of the opportunity, here afforded, of expressing our thanks to those who, since the appearance of this work, have made suggestions to us for its improvement.

WOOLSTON, HANTS,
1895.

PREFACE TO THE FIRST EDITION

ONE of the most remarkable features in the educational movement of the present day has been the increased effort to diffuse a knowledge of the relations which exist between our health and the air we breathe, the water and food we consume, the soil we tread and the buildings we occupy. Known under the various current names of Sanitary Science, Public Health or Hygiene, this subject involves an acquaintance with such diverse sciences as physics, chemistry, geology, engineering, architecture, meteorology, epidemiology, bacteriology and statistics. To these, strictly speaking, may be added the study of the law or those legal enactments which concern the sanitary well-being of communities.

When, therefore, the publishers asked us to prepare a small work on this many-sided subject, to form one of their Science Manuals, such as would present its facts and principles fully, briefly, and yet in simple language suitable for both non-professional and professional readers, we were early confronted with the difficulty of deciding what to include and what to omit.

We have endeavoured to consider the general laws of health, the causes of disease and the means of combating them, in the simplest language, and, by divesting them, where possible, of scientific technicalities, to make clear, even to non-scientific readers, those great natural laws and processes upon which our healthy life so much depends. While doing so, we have felt bound to be not unmindful of the wants of others, desirous of entering more fully into the study of what should be a great and practical subject in our national education. The work is not to be regarded as a substitute for the regular and more advanced

books which discuss the subject of hygiene in its many bearings, but rather is intended as an introductory manual for the use of junior students or others, preparatory to a more extended and practical study of public health work.

As regards chemical analysis, we have only attempted to give such details as appeared absolutely necessary in order to make the book useful to those capable of appreciating the meaning and value of results. For their practical application, laboratory experience and instruction are essential. In order to encourage uniformity of international knowledge, the metric system of weights and measures is used.

In view of the increasing public interest taken in facts and laws concerning Weather, Climates, and Vital Statistics, short chapters have been given upon these subjects, in non-technical language as far as possible.

For illustrating some part of the text, we are indebted to Mr. L. Casella for the use of drawings of various meteorological instruments, and to Mrs. Bruce for several original diagrams. In order to further illustrate the text, use has been made of four diagrams published by the Local Government Board in their annual reports.

WOOLSTON, SOUTHAMPTON,
1894.

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CHAPTER I.

AIR.

We are all familiar with the fact that the earth is surrounded on all sides with a gaseous envelope, the atmosphere (from the two Greek words, ἀτμὸς, smoke, and σφαῖρα, a globe), or, as it is more commonly called, the air.

This air, when pure, is free from colour, taste, or smell, and is really a mechanical mixture of gases, possessing the properties of weight, expansion, and diffusibility. That the air we breathe is not a chemical compound, but only a mechanical mixture, is known by the facts that the gases of which the air is made up do not exist in it in their proper combining proportions, and that the relative amounts of these gases in the air cannot be expressed by any chemical formula. Moreover, on mixing the gases of which air is composed, together in the same proportions as they exist in air, there is no manifestation either of heat, electricity, or change of volume, such as would result were air a chemical combination.

The Composition and Physical Properties of Air.

The chemical composition of the dry atmosphere or air in 100 measures or volumes may be roughly taken as being 79 of nitrogen and 21 of oxygen with a small proportion of carbon dioxide. If the calculation be made by weight, there would be in 100 parts of dry air, roughly 77 of nitrogen and 23 of oxygen. As an average of many examinations, the composition of pure air appears to be as follows:—

	By Volume.	By Weight.
Nitrogen	79·02	76·84
Oxygen	20·94	23·10
Carbon dioxide	0·04	0·06
	100·00	100·00

Besides the above gases, the air always contains a certain quantity of watery vapour, together with various impurities.

Nitrogen is the main constituent of our atmosphere. It is a chemical element found everywhere in Nature, particularly in the tissues of all animals and plants, and is essential to the existence of all forms of life. In the air, nitrogen appears to act as a diluent of the oxygen, evidently reducing its strength and rapidity of action, much as water is used to dilute spirits or wine. It is probable that the nitrogen of the air may serve to supply plants with a certain amount of nourishment in the form of oxides of nitrogen, which are washed down out of the air into the soil after storms or rain, but on this point as yet very little is known.

Pure nitrogen is a colourless, tasteless, and inodorous gas: it is quite incombustible and incapable of supporting either combustion or life; it is from this latter peculiarity that foreign chemists call it *azote*, a word derived from the Greek, meaning "no life." We English people call it nitrogen, because it is the element which gives birth, so to speak, to nitre.

Nitrogen can be easily prepared from the air, by removing, by means of phosphorus, the oxygen with which it is mixed. A piece of common phosphorus is wiped dry and placed in a small porcelain capsule floating on some water contained in a dish. A light is applied to the phosphorus and the dish quickly covered with a glass bell jar. The phosphorus having a great liking for oxygen will burn until the last trace of that gas is removed from the air under the bell jar, forming as it burns white fumes of phosphorus pentoxide. These gradually become dissolved in the water, forming in it meta-phosphoric acid, while the water itself slowly rises in the dish to occupy the space originally taken up by the air, leaving the empty space above the water filled by a colourless gas which is almost pure nitrogen.

Nitrogen may also be isolated from the atmosphere by passing air slowly over red-hot copper, which absorbs the oxygen and leaves the nitrogen.

About 1 per cent. of what for many years was considered nitrogen in the air, is now known to be an elementary gas called *argon*. It is the most inert body known, and, so far as has yet been ascertained, cannot be made to combine with any other body. Its atomic weight is apparently 39·6 or 40; its density 19·94; its freezing-point is $-189{\cdot}6^{\circ}$ C., that of nitrogen being -214° C. Argon possesses a double spectrum, in this respect resembling nitrogen and certain other elements.

Oxygen.—Although nitrogen practically constitutes four-fifths of the atmosphere, the most important constituent of the air is

oxygen. This gas, which when pure is clear and colourless, is necessary for all forms of life; all animals, if deprived of it, dying at once. It is also needed for every kind of combustion, such as the burning of wood or coal, and is necessary for every kind of light except the electric light. Oxygen exists in the air in a free state, and is not chemically combined with the nitrogen of the atmosphere, but only mixed with it.

Oxygen can be abstracted and recovered from the air by heating various metallic oxides and peroxides. For example, red lead, heated, gives off oxygen and leaves litharge or plumbic oxide: thus $2Pb_3O_4 = 6PbO + O_2$. Similarly, by the alternate conversion of a substance called baric oxide into a still higher oxide or peroxide by heating it in air and afterwards decomposing it by further heat, back to the original compound, a continuous process for the production of oxygen is obtained; thus $2BaO_2 = 2BaO + O_2$. The reason of being able to do this is due to the fact that baric oxide contains 137 parts by weight of the metal barium, combined with 16 parts by weight of oxygen, and if heated in purified air absorbs 16 parts more of oxygen forming the baric peroxide. If the temperature be still further raised, the extra 16 parts of oxygen are given off, and the baric peroxide returns once more to baric oxide, and can be further utilized again for the absorption of more oxygen from the air.

A modification of oxygen occurs in small traces in the atmosphere, and is known by the name *ozone*. This is a gas of probably great importance and is a kind of intensely strong oxygen. It is very plentiful in fresh pure air, and least so in places where there is much organic matter, or where men or animals are crowded together. Ozone is a powerful oxidizing agent, and is produced whenever an electrical discharge takes place in air due to the conversion of some of the atmospheric oxygen into the extremely active modification, ozone, which, however, can be reconverted into ordinary oxygen by the action of heat. Ozone may be readily recognized by its odour, which is so pungent that one volume present in $2\frac{1}{2}$ million volumes of air is said to be easily detected by the sense of smell. It is specially noticeable in country and sea air.

The most usual test for detecting traces of ozone in air is to expose strips of blotting paper moistened with a mixture of potassic iodide and starch, when if any ozone be present a blue tint is produced owing to the decomposition of the iodide and the formation of a potassium oxide and iodide of starch. This tint, however, is not very reliable, as there are often traces of other gases present in the air which give the same result. If such be suspected, in order to be quite sure that it is ozone only which

has turned the paper blue, it is necessary to use a second test, which is to soak red litmus paper with a very dilute solution of the iodide of potassium. The potassium oxide produced causes an alkaline reaction, and turns the red paper to blue. Although small traces of ozone constitute a powerful agent for the purification of the air from waste organic matter, in larger quantities it acts as a violent irritant to the eyes and nose.

Carbon Dioxide.—Samples of air, no matter where collected, always contain another gas besides nitrogen and oxygen, called carbon dioxide, and this usually to the extent of about 4 volumes in 10,000 of air. Carbon dioxide is a clear colourless gas containing 12 parts by weight of carbon combined with 32 by weight of oxygen. It is produced when carbon, which forms the greater part of coal, is burnt. The carbon unites with oxygen, their union producing both light and heat with the giving off of carbon dioxide gas. For this reason, it is the invariable product of the burning of animal and vegetable matter in the air, and is the choke-damp which collects in mines after an explosion. It is also largely given off by men and animals, as well as from the earth, more particularly in volcanic districts. Under the influence of sunlight, plants breathe in carbon dioxide, retaining the carbon and setting free the oxygen. In the dark, this action of plant life is reversed, the oxygen being absorbed and carbon dioxide given off. Carbon dioxide, or as it is sometimes called carbonic acid, exists largely in Nature in combination, forming compounds called carbonates. It is readily obtained by adding dilute hydrochloric acid to a form of calcic carbonate such as marble or limestone contained in a flask, and so arranged that the escaping gas can be collected into a suitable vessel. The acid acts upon the calcic carbonate, forming calcic chloride, water and carbon dioxide; this latter escapes as a gas while the two former remain behind.

Carbon dioxide is faintly acid in taste and smell, and behaves in an exactly opposite manner to oxygen, inasmuch as it can neither support life nor combustion. It is a very heavy gas, being just 22 times heavier than hydrogen, which is the lightest of all gases. It is soluble in water, but the volume so dissolved depends largely upon temperature and pressure. The amount of carbon dioxide present in the air varies according to place and season. Angus Smith found 0·36 part per 1000 of air in London streets, 0·4 in Manchester; while in country districts and on the tops of hills or mountains, about 0·3 part per 1000 of air has been the average amount found in the atmosphere. In inhabited rooms and stables, of course much larger quantities have been found. To the extent of 0·4 part in 1000 of air carbon dioxide is a normal

constituent of our atmosphere, and unless it exceed that quantity it cannot be considered an impurity.

Watery Vapour is always present in air. The presence of this in the atmosphere is due to the fact that water evaporates at all temperatures, so that a slow but invisible escape of water vapour is taking place from the earth's surface at all times into the air space which encircles the globe. If we leave a dish full of water exposed to the air, it sooner or later dries up, because the water goes away slowly in the form of vapour. This phenomenon is sometimes spoken of as the tension or elastic force of aqueous vapour, and is such that it can be measured or stated to exercise pressure equal to so many inches of mercury. The amount of watery vapour which the air can take up varies with the temperature of the air, the greater the temperature the greater the amount of water vapour which can be taken up. This explains why water dries up much quicker in warm weather than in cold. The following table shows roughly the weight of watery vapour which a cubic foot of air can hold at different temperatures:—

At 30° F.	2 grains.	At 74° F.	9 grains
" 41° "	3 "	" 77° "	10 "
" 49° "	4 "	" 80° "	11 "
" 56° "	5 "	" 83° "	12 "
" 61° "	6 "	" 86° "	13 "
" 66° "	7 "	" 88° "	14 "
" 70° "	8 "		

Or, in another way, it can be said that a quantity of completely moist air at 32° F. holds in suspension an amount of vapour equal to $\frac{1}{160}$th part of its own weight; at 59° F. $\frac{1}{80}$th; at 86° F. $\frac{1}{40}$th; at 113° F. $\frac{1}{20}$th; and at 140° F. $\frac{1}{10}$th. Expressed mathematically, it can be said that while the temperature advances in arithmetical progression, the power of the air to retain vapour increases with the rapidity of a geometrical series having a ratio of two. When air contains the full amount of watery vapour for the given temperature it is said to be saturated; and in proportion as it is more or less removed from the point of saturation, and not in proportion to the precise amount of water it contains, is air said to be dry or moist. Thus if air can hold 100 parts of moisture, but actually only holds 75 parts, it is said to be only three-quarters moist, or to have 75 per cent. of humidity. The amount of moisture in the air can be determined by causing a current of air to flow slowly through tubes containing hygroscopic substances such as caustic potash or hydrochloric acid, which have the power of taking up or absorbing water, and then by weighing to note the increase in weight which has taken place,

and knowing the exact volume of air which has been passed through, calculating the moisture present as a percentage. It is, however, more usual to determine the atmospheric moisture by means of instruments called "hygrometers," particulars of which are described in a subsequent chapter upon climate and weather.

While the amount of watery vapour in the air has a considerable effect upon the temperature of a place, its presence is absolutely necessary for life. A perfectly dry air not only would be unbearable, but would quickly prove fatal to both plants and animals. As a rule, the atmosphere contains from 1 to $1\frac{1}{2}$ per cent. of water in a state of vapour, or from 50 to 75 per cent. of the amount required for complete saturation. If the quantity be much above or below these limits, the air is either unpleasantly moist or dry.

The air being really nothing more than a mixture of gases, behaves exactly as and has the properties of a gas; that is to say, it has weight, expansibility, and diffusibility. Like any solid or liquid, the air has **weight**. That this is the case is shown by the fact that if a glass globe of known capacity be taken, exhausted of all air by means of an air-pump and then weighed, its weight then will be less than it would be if air were allowed to enter it. If the capacity of the globe be known, the difference between the two weights is the weight of that volume of air. By a modification of this method, and the exercise of certain precautions, the weight, not only of air, but of other gases, has been accurately determined. From experiments of this kind, it has been found that air is 773 times lighter than water, and that 100 cubic inches of dry air, when the thermometer is at 60° F., and the barometer is at 30 inches, weigh 31 grains; under the same conditions, the same volume of carbon dioxide gas weighs $74\frac{1}{4}$ grains; while 100 cubic inches of hydrogen, which is the lightest known gas, weigh only $2\frac{1}{7}$ grains.

Since the air, therefore, has weight, it gives rise to *pressure* according to the same laws as those by which the weights of liquids produce pressure. If we imagine an upright cylinder, some miles in height, full of air and resting upon the ground with its top closed, and consider the air contained in the bottom ten feet of the cylinder, we can readily realize that this lower portion of air must support the weight of all the air above it, and transmit that weight to the ground beneath it, and also to the curved sides of the cylinder which contain it, and that in a direction at right angles to the surface. Thus the pressure of the air in this imaginary cylinder increases from the top of the column to its base, and is equal to the weight of that column,

If we regard the atmosphere as a kind of fluid sea, some 40 miles in depth, surrounding the earth on all sides, we can realize that it exercises the same pressure as if it were a liquid of very small density. This pressure will be at right angles to any surface, and will lessen as we ascend from, and increase as we descend to, the level of the earth. As it has already been stated that the weight of 100 cubic inches of air is no less than 31 grains, it will be easily understood that the whole earth's atmosphere, which has been estimated to be not less than 40 miles in height, really exercises a very great pressure upon the earth's surface. The exact amount of this atmospheric pressure was first determined by an experiment made in 1643 by Torricelli, a pupil of Galileo, which may be explained as follows:—A glass tube, closed at one end, is taken, having an internal diameter of ¼ inch, and being a yard long. After filling it quite full of mercury, and then stopping up its open end firmly with the finger, turn it upside down, and insert its open end into a vessel containing mercury. As soon as the finger is removed, the mercury will be seen to fall slowly in the tube, until, if the observation be made in the south of England, it stands about 30 inches higher than the surface of the mercury in the vessel. This vertical column of mercury will remain at 30 inches, in height, because it is prevented from falling any lower in the tube by the counterbalancing weight or pressure, as it is called, of the air. If this same experiment be performed on the top of a mountain or high land, the length or height of the mercurial column supported by the air will be less than 30 inches, because at elevated places the height and consequently counterbalancing weight of the atmosphere is less than at places at a lower level.

By a law of hydrostatics, the heights of two columns of liquids in communication with each other are inversely as their densities; hence it follows that the pressure of the atmosphere is equal to the weight of a column of mercury, the height of which is 30 inches. If, however, the weight of the atmosphere diminishes, which it does do in elevated places, the height of the column which it can sustain must also diminish. In the foregoing experiment, the sectional area of the tube may be taken to be equal to one square inch, and since the height of the column of mercury is 30 inches, the mercurial column is really one of 30 cubic inches. As a cubic inch of mercury weighs 3433½ grains, or as near as possible half a pound, the pressure of that column of mercury on each square inch of surface is equal to 14¾ pounds. On a square foot, this would give a pressure of nearly a ton; and as the average superficial area of an ordinary man is 16 square feet, the pressure supported by such a man amounts to nearly

16 tons. This at first sight seems an impossible burden, but the effect of this enormous force is equalized by the contrary and equal pressure of it in all directions upon the body surface, whereby we are rendered totally unconscious of its existence. The instruments used for measuring atmospheric pressure are called barometers; their varieties and special features are discussed in a subsequent chapter.

Though the total weight of the atmosphere must always be the same, still its density, and consequently the pressure which it exerts, will vary according to local conditions. The most prominent of these conditions are its temperature and its degree of dryness. Like every other gas, air expands with heat, and assuming no variation in pressure, this is (according to the law of Charles) at the rate of $\frac{1}{491}$ or 0·00203 of its volume for each degree Fahrenheit; or $\frac{1}{273}$ or 0·00367 for each degree Centigrade. For this reason, a given volume of air at 50° F. is lighter than the same volume at 40° F.; and a cubic foot of air at 0° C. would weigh just twice as much as a cubic foot of air at 273° C. Similarly, moist air is lighter than dry air. The reason of this is as follows:—Air is really a mixture of 4 volumes of nitrogen (atomic weight being 14) and 1 volume of oxygen (atomic weight being 16). Each volume of air, therefore, is represented by $\frac{4 \times 14 + 16}{5} = 14{\cdot}4$. Now, moist air is air, *plus* water, in a gaseous or vaporous state; but water itself is a compound of 2 volumes of hydrogen (atomic weight 1) and 1 volume of oxygen, and as a compound gas, occupying 2 volumes, is represented by $\frac{16 + 2}{2} = 9$. That is to say, a volume of dry air weighs 14·4 and one of water vapour only weighs 9. These variations in the weight of hot or cold, dry or moist air are indicated by corresponding fallings or risings of the barometer, and explain why in England the barometer rises during dry easterly winds and usually falls with the damp westerly winds.

The **Expansibility** of air, which plays a very important part in the theory and practice of ventilation, as we shall see later on, is really dependent upon two conditions; namely, the pressure under which it is, as expressed by the barometer, and the temperature at the time being. For a due appreciation of this power of air to constantly change its volume, it is necessary to understand and apply the two physical laws of Boyle and Charles. The law of Boyle is, that "the temperature remaining the same, the volume of a given quantity of air or gas is inversely as the pressure which it bears." In other words, this means that if a cubic foot of air is measured at 29 inches of barometric pressure,

to know what it would measure, were the pressure 30 inches, it must be multiplied by 29 and divided by 30. Or, that a quantity of air which exactly measured 1 cubic foot at 29 inches of barometric pressure would only measure 0·96 cubic foot had the pressure been 30 inches, because $1 \times \frac{29}{30} = 0·96$ cubic foot.

The law of Charles, which has already been alluded to, is, that "assuming no change in pressure, any gas or air expands or contracts $\frac{1}{491}$ (·00203) of its volume for every degree it is above or below 32° F. in temperature." If the temperature be on the centigrade scale, the ratio of expansion or contraction is $\frac{1}{273}$ (·00367) for each degree above or below 0° C. In other words, this means that 491 volumes of air at 32° F. become 492 at 33°, 493 at 34°, and so on. That is, as 491 *plus* or *minus* the given temperature is to 491 *plus* or *minus* the required temperature, so is the given volume to the required volume. As an example, we can say 100 volumes at 30° F. will become 104·09 volumes at 50° F.: because as $491 - 2\ (489) : 491 + 18\ (508) :: 100 : x = 104·09$ volumes.

In actual practice, it is usually needed to make these two calculations or corrections together. For instance, suppose in a room with the temperature at 40° F. and the barometer at 30 inches, the volume of air was 1000 cubic feet, what would be the volume of that same air were the temperature to be raised to 60° F. and the pressure fall to 29 inches? Using the two equations combined, as follows—

$$\frac{30}{29} \times \frac{491 + 28}{491 + 8} \times 1000 = 1075 \text{ cubic feet,}$$

we get that, under these altered conditions of pressure and temperature, what before measured 1000 cubic feet now measures 1075 cubic feet, consequently the excess of 75 cubic feet would escape out of the room.

It is only by rightly comprehending the great property of the atmosphere to expand or contract according to the above-mentioned laws, that we can fully appreciate the causation or production of those movements of the air over larger or smaller regions which we in everyday life call winds or draughts. They are due to the simple fact, as already explained, that when over some large tract of land the air is warmed by the sun, it expands and rises, while from adjoining regions colder and heavier masses of air rush in to take its place. Similar but smaller movements of air, due to varying degrees of heat, density, and pressure, are constantly going on in and about our houses. It is the same cause which makes the warm air over a fire go up the chimney to be replaced by fresh and colder air entering by windows, doors,

and cracks. Whenever a room or house is inhabited by human beings or warmed by lights and fires, a constant expansion of air is going on with an escape of the excess volume by the chimneys and doors or windows. By this means the equilibrium between one part of a dwelling and another is constantly being disturbed, and the air rarely if ever allowed to be absolutely still even over the most limited area.

From what has already been said, it will be gathered that, while the atmosphere has several constituents, each of them has its own particular weight; that while the carbon dioxide is heavier than the oxygen, this again is heavier than the nitrogen, while the water vapour is lighter still. If the same laws or rules held good for gases as regulate fluids, we should expect that these various constituents of the air would form themselves into layers with the heavy carbon dioxide near the ground, next above it the oxygen, then the nitrogen, and, above all, the watery vapour. As a matter of fact such is not the case, because of the action of another great law of Nature, known as the law of the diffusion of gases, which is such that it causes all gases to mix one with the other, no matter how they differ in weight.

The **Diffusibility** of a gas is well and easily shown by the following simple experiment: Take a U-shaped tube some 18 inches long, fix it at one end by a cork to a porous cell such as is used in electric batteries, and then fill the tube nearly full with some water. Next make some hydrogen, and fill with it a bell jar. If this bell jar containing the hydrogen be quickly placed over the porous pot, the hydrogen gas so rapidly diffuses through the pores of the cell or pot into the tube that the water is at once driven down, and spurts out at the open end. So, again, if we take two globes, and, having filled the lower one with carbon dioxide and the upper with hydrogen, connect them together by a tube, although the hydrogen was in the upper globe, yet, after a short time, half of it will have gone down into the lower globe and half of the carbon dioxide will have ascended into the upper one. Now we know carbon dioxide to be just 22 times as heavy as hydrogen, yet the power of diffusion is so great that it has overcome the enormous force of gravity.

The rate at which this intermingling of gases can occur is largely influenced by their weights (densities). So much so that, according to the law of Graham, who first explained the fact in 1832, it is enunciated that "the force of diffusion is inversely as the square roots of the densities of gases." Thus, if we take two vessels of equal size, the one containing oxygen and the other hydrogen, and separate them by means of a porous plug, we shall find diffusion take place, and this will be in the proportion of 4

parts of the hydrogen into the oxygen to every 1 part of the oxygen into the hydrogen. This exact ratio of diffusion is explained by the fact that the density of the hydrogen is 1 as compared with the 16 of oxygen, hence the force of the diffusion is inversely as the square root of these numbers—that is, it is inversely as 1 is to 4, or just four times as great in the one which has one-sixteenth the density of the other.

It is this faculty of diffusion, possessed by all gases, which is the chief cause by which the composition of the air is kept constant, and which causes the carbon dioxide formed so freely in our large towns and cities by combustion and breathing to be rapidly removed from where it is formed to other parts, where the processes of vegetation and sunlight can break it up into carbon for the food of plant life and oxygen for the use of men. It is this remarkable action of the green colouring matter of plants, called chlorophyll, upon carbon dioxide, which is the great compensating agency at work for keeping down the tendency of carbon dioxide to increase, and whereby Nature gets rid of what practically is the chief impurity in the air, with the result that the carbon dioxide in the atmosphere at the top of a mountain is in much the same proportion as in the air at its foot—namely, that it rarely reaches a proportion of more than 0·04 per cent., an amount which is quite harmless to human life. Supplementary to the power of gaseous diffusion, we have the action of winds, which scatter and diffuse over a large area many impurities of the air which would be very hurtful if confined to any limited space. In a similar but lesser sense, dew, rain, and snow may be regarded as helping in the constant purification and dispersion of atmospheric impurities.

THE IMPURITIES OF THE AIR.

Although the examination of pure air indicates it only to consist of nitrogen, oxygen, a definite amount of carbon dioxide, not exceeding 0·04 per cent., and some watery vapour, the majority of samples of ordinary air betray the presence in them of various impurities, notably traces of ammonia, nitric acid, nitrous acid, various compounds of carbon—chiefly carbon dioxide, carbon monoxide and carburetted hydrogen,—with a greater or less amount of suspended matter, such as soot, dust, epithelial cells, vegetable fibres, wool and silk fibres, particles of sand, chalk, or iron, and the minute forms of life. These impurities of air are mainly the results either of combustion, respiration, emanations from sewers, marshes, or graveyards, or else the contaminations given off by manufactures and trade processes.

Ammonia is a compound containing 14 parts by weight of nitrogen along with 3 parts by weight of hydrogen. It is a colourless gas, marked by an intensely pungent odour, and quite unable to support combustion. Although traces are usually present in most air samples, it rarely exists in the atmosphere in greater amount than 3 parts in ten million, and is formed in the main from the decomposition of decaying nitrogenous matter. When present, ammonia is usually in combination with some acid, such as nitric or carbonic. Being readily soluble in water, ammonia is quickly washed out of the air by rain, and carried down into the soil, in which it affords a valuable food for plants. Chemically, ammonia represents the main part of what is called the organic matter in the air, and if condensed in water, yields the so-termed albuminoid ammonia.

Nitric and **Nitrous Acids** are probably derived by the air in small quantities from decaying nitrogenous matter, while, too, a certain amount is produced in the air by the direct combination of oxygen and nitrogen during electrical disturbances. These acids, like ammonia, are washed down by rains into the soil, and there serve in the fertilization of various forms of vegetation.

Carbon Dioxide has already been shown to exist to a limited extent in pure air. This limit has usually been placed at 0·04 per cent., or 4 parts in 10,000 of air; but it is probable that this limit is too high, and that in the purest airs the natural amount of carbon dioxide does not exceed 0·03 per 1000 volumes. Any carbon dioxide present in air, therefore, over and above 0·04 per cent., must be regarded strictly as an atmospheric impurity. This gas we know to be largely given off into the air by men and animals during breathing, by all processes of combustion or putrefaction, and by certain kinds of soil; it is increased by fogs, but lessened by rain, winds, vegetation, and ventilation. The amount in the air is consequently variable, as will be seen by the following table, showing the various quantities found in different places by various observers:—

	Carbon dioxide per 100 of air.
National Schoolroom in Leicester (Weaver)	0·241
Public Library reading-room ,,	0·206
Assize Court, Manchester (Smith)	0·196
Tailor's workshop, Glasgow ,,	0·217
Strand Theatre, London ,,	0·101
Chancery Court, London ,,	0·193
Bedroom at night (de Chaumont)	0·230
Gosport Barracks ,,	0·060
Aldershot Barracks ,,	0·049
Street in Manchester (Smith)	0·040
Mine in Cornwall ,,	0·785
Chatham Convict Prison (de Chaumont)	0·169

In some places, notably mineral-water factories, where carbon dioxide is largely made and used in the manufacture of aerated waters, the air often contains as much as from 2 to 5 parts per 1000; on the other hand, the air in a London street on a breezy day has been found to have as little as 0·36 per 1000. Carbon dioxide in its pure form is fatal when present to the extent of 75 parts per 1000, while 15 parts per 1000 gives rise to giddiness, faintness, headache, and shortness of breath; anything below 10 parts per 1000 appears to produce no effect immediately on health. In fatal quantities the action of carbon dioxide is that of a narcotic poison producing insensibility and deep sleep. The amount of carbon dioxide given off by respiration is estimated by deducting the amount present in the outside air, or, what is usually the same thing, 0·04 per cent. from the total carbon dioxide present. Thus, if in a hospital ward or schoolroom the air was found to contain 0·78 of carbon dioxide per 1000 parts of air, deducting 0·4 as being normally present in the atmosphere, we should have 0·38 part per 1000 as a carbon dioxide impurity due to respiration and other causes. We are all familiar with the heavy unpleasant smell or stuffy feeling present in all ill-ventilated or crowded rooms. In connection with this it has been observed that anything under 0·2 part per 1000 over and above the 0·4 usually present in the air—that is, a total of 0·6 per 1000—is not associated with any atmospheric impurity capable of being perceived by the sense of smell. For this reason, this quantity is regarded as unavoidable and harmless, and, as such, a permissible impurity. The moment the carbon dioxide exceeds this quantity, the accompanying organic and impure matters present in the air become perceptible—so much so that the following scale has been proposed, namely, "rather close" = 0·4; "close" = 0·6 (1·0 total); "very close" = 0·8 (1·2 total); beyond this amount the sense of smell does not seem able to distinguish. The temperature and degree of moistness of the air have an influence upon the readiness with which the smell of organic impurities is perceived. In order to correctly judge the extent of atmospheric foulness by the sense of smell, it is necessary that the observer should have been at least some half-hour or so in the outer or fresh air, as the sense of smell is very rapidly dulled by foul air—so much so that the occupants of rooms containing impure air are rarely aware of its state.

Though the prolonged stay in crowded or ill-ventilated rooms whose atmosphere is markedly impure, as evidenced by a high ratio of carbon dioxide, is invariably associated with headaches, faintness, giddiness, etc., it is not to the heat or even to the carbon dioxide itself that these ill effects are

due. The effects are really and generally recognized to be due partly to the reduction of the oxygen in the atmosphere, and partly to the presence in the air of the so-called organic and other hurtful products given off by the lungs and skin. The estimation of the amount of this oxygen reduction and general organic impurity is much less easy than the estimation of the presence of carbon dioxide, and as the amount of this gas appears to bear a more or less constant ratio to these other organic impurities, its estimation is usually accepted as the index of atmospheric purity or impurity. The precise nature of this organic matter present in air fouled by human respiration is undetermined. We know that, in addition to some 30 to 40 ounces of water, large quantities of organic matter are given off from the skin and lungs during twenty-four hours; the amount of this latter has never been precisely determined. In nature it is partly epithelium and other matters detached from the skin and mouth in a state of suspension, and partly of an organic vapour from the lungs and mouth. If collected from the air by condensation or by washing respired air in distilled water, it decolourizes permanganate of potassium, is precipitated by silver nitrate, blackens platinum, yields ammonia, and is, moreover, fœtid; thereby betraying its nitrogenous and oxidizable nature. It is readily absorbed by wool, feathers, damp walls and paper. It has a remarkable tendency to cling to parts of a room, diffusing slowly. Milk or other food left in contact with it readily becomes tainted, accompanied with a rapid growth of organisms. The general effect of air containing the organic matter produced by respiration is usually very marked upon human beings; producing heaviness, lassitude, headache, and often sickness. From experiments made upon animals, after the watery vapour and carbon dioxide had been removed and the organic matter alone left in the air, it was found to be highly poisonous, so much so that a mouse died in 45 minutes; while the historical episodes of the Black Hole of Calcutta, and the steamship *Londonderry*, in which 200 steerage passengers were forced on a stormy night to occupy a small cabin 18 feet by 11, and 7 feet in height, with the result that 80 persons were found dead the next morning, only too well emphasize its equally noxious effect on men and women.

The continuous breathing of a moderately vitiated atmosphere is not less hurtful to health. It induces a general lowering of the vital processes, with loss of strength and nutrition, to say nothing of an indirect influence towards both physical deterioration and general moral degradation. It is only too probable that to this cause, as much as to defective feeding, must be attributed the

impaired vitality and health of many of the poorer inhabitants of our crowded towns and villages.

While, of the carbon compounds found as impurities in air, carbon dioxide represents the main impurity due to respiration and combustion, there are several other gaseous impurities constantly added to the air as the result of the combustion of coal, coke, coal gas, etc. Among them are carbon monoxide, carburetted hydrogen, sulphurous acid, and sulphuretted hydrogen.

Carbon Monoxide is a gas produced by the combustion of carbon in an atmosphere of carbon dioxide, and is frequently formed on the surface of charcoal stoves not exposed to air currents. This gas is extremely noxious, less than 5 volumes per 1000 being able to produce poisonous symptoms, such as dizziness, headache, confusion of ideas, with a feeling as if a tight band encircled the forehead and temples. In extreme cases, this gas causes suffocation by displacing the oxygen out of the red corpuscles in the blood. The presence of carbon monoxide is always a sign of imperfect combustion, such as occurs when coke is burnt in an open grate, and is especially apt to be generated by cast-iron stoves. This appears to be due to the fact that a portion of the carbon dioxide evolved during the combustion of carbon is changed by heated iron into carbon monoxide, and that heated iron, more particularly cast iron, while generating and absorbing this gas by its internal surface, permits it to diffuse continuously from its external surface into the surrounding air. It is chiefly owing to this fact that the employment of stoves in this country has never been regarded with favour.

Carburetted Hydrogen, though often present as an impurity in air, as the result of combustion of coal, is a comparatively harmless gas. It is often present in small quantities in mines, and appears to do no harm. In large quantities, such as 300 parts per 1000, it seems to produce some poisonous symptoms, such as vomiting and convulsions. From its occasional presence in the air over marshes, this gas is often called "marsh gas." Another name for it is "methane."

Sulphurous Acid and sulphuretted hydrogen are, among other impurities, added to air by combustion processes. The former is a constant impurity in the air of coal and gas burning towns, where it often exists in sufficient quantity as to redden, after a few hours' exposure, moist blue litmus paper. The presence of this gas in the air of large towns is one of the chief causes of the difficulty experienced in cultivating shrubs or trees; while, too, when washed down by rain, it materially retards the growth of grass.

Sulphuretted Hydrogen, which is a disagreeably smelling gas,

may be found in the neighbourhood of gasworks, chemical factories, sewers, and marshes. In mines it often exists from the decomposition of iron pyrites, which is ferrous sulphide. If present in large quantities, this gas discolours paint, owing to the formation of lead sulphide. As a rule, this gas has no ill effects upon health, but a few cases have been reported, notably that of men digging out the Thames Tunnel, in which the continued breathing of this gas has given rise to serious symptoms. In acute cases, these appear to be those of a narcotic and convulsive poison; while in chronic cases, more of the nature of anæmia, diarrhœa, and general sickness.

Suspended Matter.—The impurities of the air which we have so far considered are only gases, and, on the whole, generally diffused or distributed; but, besides these, there are certain impurities which are more or less solid, and only exist at or near the spot where the cause for them is to be found. We are all familiar with the fact that, if a beam of sunlight pass through a chink or crevice into a darkened room, its course is made visible to us by some of the light being reflected by minute particles of suspended matter. The particles which comprise this suspended matter, or solid impurities of the air, are of the most varied nature: some of them are inorganic, some organic, some absolutely harmless, some truly hurtful. Except in certain places, such as on the top of mountains or out at sea, it is difficult to find any air which is absolutely free from all suspended matter, while in towns and factories the atmosphere is usually heavily laden with many solid particles. How far these suspended matters or impurities in the air will affect our health, depends much upon their quality or nature, and not so much on their mere quantity; but this latter, in some cases, is not a negligeable point. Chief among the *inorganic* suspended matters of the air will be found fine grains or particles of sand, coal or carbon, clay, common salt, and oxides of iron. As a rule, these solid inorganic suspended matters of the air, consisting of dust of various kinds, though extremely injurious to health if in excess, are only so by virtue of their mechanical irritating influences upon the eyes and lungs. It is their physical conditions as to roughness, angularity, or smoothness, rather than their mere nature, which influences their power for evil. Various affections of the lungs, notably phthisis, or consumption, have been traced among classes of work-people as being due to the breathing in by them, during work, of the finer dust products of their particular trades or businesses. For instance, among tin-miners lung disease is prevalent, owing to the fine particles of tin-dust inhaled by these workers; similarly, the fine dust from iron mechanically irritates the air-passages, and

gives rise to considerable ill-health among needle-makers, saw-grinders, and cutlers. So, too, among potters, a peculiar asthmatic cough is often set up in consequence of the continued breathing of the finer clay dust. The makers of cement, grindstones, and certain kinds of glass suffer in the same way. In white-lead works, the lead dust gives rise to colic amongst the workers, while workers in copper and brass foundries are subject to a special form of non-periodic ague, and among match-makers the fumes and particles of phosphorus used in making matches, when inhaled, are apt to give rise to disease of the maxillary bones.

The *organic* suspended impurities of the air vary, even more than the inorganic, with the locality, both in kind and number. Among the more common are starch cells, pollen grains, and minute seeds of plants, pieces of wood, fine fragments of flax, wool, cotton, and silk, together with fatty particles, scales of hair or skin, and germs of disease. The majority of these are, of course, harmless. That the disease known as hay fever or summer catarrh is produced in many by the pollen from grasses is too familiar to be doubted. In the carding-rooms of cotton, flax, wool, and silk factories the finest dust from off the special fabrics is often so great and so irritating in nature in the atmosphere of the work-rooms that considerable ill-health results to those employed in them. Though it is somewhat disgusting to think that particles of fat and scales of hair or skin are floating about in the air, that such is the case is none the less true, and is, moreover, a not infrequent means of carrying disease from one person to another. Thus pus cells from ulcers and sores may give rise to a very infective form of inflammation of the eyes or even erysipelas, and the dried particles of expectoration from the lungs of those suffering from consumption, floating in the air, can convey that disease to those compelled to breathe such tainted atmosphere; in a similar way, the dried scales of skin from those sick with smallpox, scarlet fever, or measles may carry these diseases to the healthy. Though the germs of disease thus capable of being carried from one person to another by floating through the air can only doubtfully be supposed to find any nourishment and actually grow in the air, it is equally clear they can retain their power of growth for some time while thus suspended in the atmosphere. This is probably to be explained by the fact that these germs of disease, be they associated with bronchial expectoration or with scurf and scales from the skin, are really living organisms existing in the various forms of bacteria, bacilli, micrococci, and other types of microscopic life. As such they differ widely amongst themselves, not only in form and shape,

but as regards preparedness for development. Some are rod-like bodies, long and thin; others are but circular spheres of protoplasm; some are dry, others moist; some are fresh, others old. In some the hatching period is long, in others short: how soon or how readily they will infect any one depends largely upon the different degrees of resisting power of the particular germs and of the individual. A healthy subject may breathe in these germs and probably no ill effects follow, but if they find a place in some system, weakened by faulty modes of life, the probability is they will give rise to disease.

Numerous experimental observations have indicated that from 1 to 22 micro-organisms per litre of air are present in the atmosphere of four-roomed houses in excess of those present in the outside air, and that in very small tenements, consisting of only one or two rooms, the excess is from 6 to 240 per litre of air. Without attaching too much importance to the actual number of micro-organisms found or present in the air, it appears that the proportion between the moulds and bacteria present is a matter of considerable interest. The ratio of bacteria to moulds increases with vitiation of the air, because bacteria come principally from the walls, floors, and occupants of a room, while the moulds come principally from the outside. While in the outer air, the bacteria may stand to moulds in the ratio of only 2·5 to 1, in four-roomed houses the ratio is often 21 to 1, in single-room tenements 49 to 1, and in crowded and imperfectly ventilated public rooms, such as school, as much as 132 to 1. Experience suggests that in a properly ventilated space the bacteria should not exceed moulds in a greater ratio than as 30 to 1, and that the total number of micro-organisms should not exceed 20 per litre of air.

Sewage Emanations.—Air rendered impure by emanations from sewage, whether from drains, sewers, or cesspools, is undoubtedly capable of giving rise to ill-health, more especially in the form of sore throats (diphtheritic or otherwise), diarrhœa, and gastro-intestinal disturbance. The composition of such air is such that its oxygen is lessened, its carbon dioxide increased, and that there is much organic matter together with varying amounts of sulphuretted hydrogen present. The numbers of micro-organisms present in the suspended matter of such air is not always increased. How far the bad effects following exposure to sewage-polluted atmosphere is due to any one individual impurity is uncertain, but the evidence is strong that either some specific poison is carried by sewer emanations to the general atmosphere, or else their effect is powerfully to predispose to disease. It is probable that sewer emanations differ largely in their specific powers for evil, according as to whether the generating sewer be

adequately ventilated or not, as evidenced by the good health enjoyed by men working in well-ventilated and well-constructed sewers as compared with those employed in sewers which are ill ventilated and otherwise faulty.

Marsh Emanations.—In the neighbourhood of marshes the air is often impure; more especially being characterized by an excess of watery vapour, carbon dioxide, carburetted hydrogen, hydrogen, and sulphuretted hydrogen. Marshes have long had ill-repute owing to the prevalence of malaria in their vicinity. In the light of modern knowledge, this connection of malaria with marshes depends, not upon any special emanations of gases, but upon the fact that water-logged lands and marshes afford suitable breeding-places for certain kinds of gnats, or mosquitoes, which are necessary for the diffusion of the malarial micro-organism from man to man.

The air of **Brickfields** and **Cement Works**, though usually characterized by a distinct smell, cannot be shown to be sanitarily impure. The exact cause of the odours prevalent is not known, and though the air issuing from the chimneys of furnaces and kilns is rapidly fatal, so rapidly is it diffused and diluted that at a very short distance it is quite respirable. The chief evil of the smoke and gases escaping into the air from cement works appears to be its destructive effect upon all adjacent vegetation.

In former years, much atmospheric pollution occurred in the neighbourhood of copper, alkali, and chemical works generally, from the pouring out of fumes of sulphurous, sulphuric, and hydrochloric acids, along with sulphuretted hydrogen and ammonium sulphide. At the present day this has to a great extent been remedied.

The Theory and Practice of Ventilation.

From the preceding pages we have learnt that, while the average composition of pure air is practically constant, the nature of the impurities in the atmosphere is less so. In the ordinary sense in which the term ventilation is used, we may regard it as the removal or dilution of all the impurities which can collect in the air of inhabited rooms. These impurities, we have seen, may be derived from various sources, such as respiration, exhalations from the skin, the combustion of fires and lights, the presence of filth, dirt, or putrefying matter, and even the escape of emanations from sewers, drain-pipes, and other impurities under or outside our houses.

In practice, we may limit the term ventilation to the dilution or removal, by a supply of pure air, of the products of respiration

and of combustion in ordinary dwellings, coupled in the case of hospitals with the additional impurities resulting from the presence of sick persons. For the removal of all other air impurities, ventilation ought not to be required, because, strictly speaking, these should be avoided by the exercise of due cleanliness and the maintenance of a proper system of drains and sewers, combined, moreover, with a general attention to the sanitary condition of the neighbourhood of our houses. Before proceeding, however, to determine how much fresh air is required for the above-named purpose, and as to how this supply can be best attained, it is necessary to inquire with some detail what are the precise amounts of the impurities added to the air of our houses as the results of both respiration and artificial lighting and warming. To a large extent these latter may be ignored, as the products of the combustion of coal, used in artificial heating, escape for the most part by the flue of a stove or by the chimney of an open grate, and as such, do not materially add to the contamination of the atmosphere of a room; it is therefore unnecessary to enter into any great detail regarding them.

Impurities due to Respiration.—It will be a material aid to our conception of the amounts of the impurities added to the air by respiration, if we recall the facts that while the air breathed into our lungs contains about 79 per cent. of nitrogen, 21 per cent. of oxygen, and 4 parts in 10,000 of carbon dioxide, the air breathed out by the lungs contains 79 per cent. of nitrogen, about 16 per cent. of oxygen, 3 to 4 per cent. of carbon dioxide gas, and some $1\frac{1}{2}$ per cent. of watery vapour, the remainder consisting of organic matter. In other words, this means that the oxygen has been lessened by about one-fourth, the carbon dioxide increased just about one hundred times, with the watery vapour, ammonia, and organic matter also increased.

A healthy adult man at rest breathes from 14 to 18 times a minute, and allowing that at each inspiration 25 cubic inches of air are taken in, the total quantity of air which passes into and out of the lungs in the twenty-four hours is about 686,000 cubic inches or 15·6 cubic feet in each hour. This amount is, however, largely increased by exertion, and may, in the case of a man doing great labour, reach as much as some 1,600,000 cubic inches in the same time. If we assume that the expired air contains only 4 per cent. of *carbon dioxide*, the average man at rest evolves nearly 16 cubic feet of this gas in the twenty-four hours, or 0·66 cubic foot per hour; during hard work the amount evolved is something like 37 cubic feet in twenty-four hours, or say 1·6 cubic foot per hour.

The quantity of *watery vapour* given off from the body is greatly influenced not only by the different degrees of muscular

exertion and repose, but also under the ever-changing degrees of moisture of the atmosphere. Speaking roughly, 10 ozs. are given off by the lungs and some 20 ozs. by the skin in the day. This is equivalent to about 550 grains per hour. If we assume the average temperature of occupied rooms to be 60° F., this means enough moisture is given off by the human body every hour sufficient to saturate 90 cubic feet of air. It is this tendency to become saturated with moisture from the lungs and skin that makes the air of crowded and unventilated rooms so uncomfortable. Carnelley's experiments show that for every part of carbon dioxide found in the air, 2·7 volumes, or 1·1 part by weight of moisture, have been given off by each person inhabiting the room.

As already explained, although the carbon dioxide added to the air by respiration and other processes is not of itself a very great impurity, yet it occurs in such constant relationship with the more important and potent organic matter as to be taken and accepted as the most convenient index of the amount of the general impurities added to the air by respiration. The amount of this gas, then, given off daily by an ordinary man in repose may be taken to be some 16 cubic feet, or 0·66 cubic foot per hour; in light work it is about 0·95 cubic foot, and in harder work from 1·6 to 1·95 cubic foot per hour. In the case of females, the figure is about 0·5 cubic foot, and for a child 0·3 cubic foot; or, as an average for a mixed community, 0·6 cubic foot may be accepted.

Impurities due to Artificial Lighting.—Turning now to the question of the precise amounts of impurity added to the air consequent upon artificial lighting, we find that the chief sources of light are candles, oil, and coal gas, and that the chief products of the more or less complete combustion of these illuminants are carbon dioxide and water, with the addition, in the case of gas, of several products of the combustion of sulphur. Now, the unit adopted in this country for the measurement of all lights is a sperm candle of a size known as "sixes," burning 120 grains per hour, and which gives a light known as "one candle power." Such a candle, on analysis, is found to contain—

Carbon	80·0 per cent.
Hydrogen	13·0 ,,
Oxygen	6·6 ,,

and on complete combustion yields equal volumes of carbon dioxide and water to the air, namely, 0·41 cubic foot.

The French unit of light is the light given out by one Carcel burner, and equals 9·3 English standard candles.

What is known as Vernon Harcourt's standard flame gives a light equal to that of one English standard candle. It consists

of an air-gas flame, $2\frac{1}{2}$ inches in height, rising from an opening $\frac{1}{4}$ inch in diameter. The flame is that of a mixture of air and pentane: 576 volumes of air being mixed with one of liquid pentane at 60° F.; or, if both are in the form of gas, 20 of air to 7 of pentane. Pentane is a hydrocarbon occurring in petroleum and in the light oil obtainable from Cannel coal.

Although various kinds of oil have been employed for illuminating purposes, paraffin, owing to its cheapness and high illuminating value, is the only one in extensive use. Ordinary paraffin, on analysis, gives the following composition: —

Carbon	86·0 per cent.
Hydrogen	14·0 ,,

When burnt in the better kinds of lamp, the average consumption per candle power of this oil is just 62 grains per hour, giving off on combustion in that time 0·28 cubic foot of carbon dioxide and 0·22 of a cubic foot of water vapour. Formerly, rape-seed or colza oil was largely used for lamps, but now it is replaced by the mineral oils, paraffin and petroleum. Colza oil is remarkably safe, but is expensive, and needs a special lamp for its use, owing to its viscid nature and the difficulty in getting it to ascend the wick.

All oil-lamps should have a suitable reservoir for the oil. This should always be made of metal and not of glass or china, as these latter break easily and cause the oil to escape. The reservoir ought to hold at least half a pint of oil for each wick in the lamp. It should never be filled quite up to the top, nor be allowed to burn quite dry. If too full, the oil may overflow and catch fire; or when burnt to the last drop, the smouldering wick may set fire to an explosive mixture of oil-vapour and air which tends to collect inside the empty and hot lamp. Much of the success of oil-lamps depends upon the proper regulation of the draught to the flame by the length of the chimney and the placing of a suitable inlet for air through a perforated metal below. These are points usually seen to by the makers. Defects of this nature check complete combustion of the oil, and are the cause of the lamp smelling. All lamps should be provided with a patent extinguisher.

The chief popular illuminant is gas. Ordinary gas is obtained by the destructive distillation of coal, free from contact with the air, and consists of a mixture of several gases, varying largely, of course, upon the kind of coal used and the methods of purification. The following statement of the analysis of two London gases made by Professor Lewes may be accepted as fairly representing the composition of coal gas generally: —

	South Metropolitan Gas Company.	The Gaslight and Coke Company.
Hydrogen	50·16	53·36
Saturated hydrocarbons	36·25	32·69
Unsaturated "	3·50	3·58
Carbon monoxide	5·68	7·05
Carbon dioxide	0·00	0·61
Nitrogen	4·10	2·50
Oxygen	0·31	0·21
	100·00	100·00

These constituents of coal gas may be divided into three groups—the illuminants, the diluents, and the impurities. The *illuminants* are hydrocarbon gases, more particularly ethene or olefiant gas, acetylene, and benzene vapour; they constitute about 4 per cent. by volume of the coal gas, and are referred to above as unsaturated hydrocarbons. The *diluents* are gases which, without conferring much luminosity on coal gas when burnt, yet serve the important purpose of diluting down the heavy hydrocarbons, which by themselves would yield a smoky flame. They are hydrogen, carbon monoxide, and saturated hydrocarbons such as methane or marsh gas. The *impurities* consist of nitrogen, derived from a little air getting into the retorts when opened for the purpose of recharging, and of some carbon dioxide, and traces of sulphur compounds, which may have escaped removal in the purifiers.

Every cubic foot of ordinary coal gas yields on combustion roughly half its own value, or 0·52 cubic foot of carbon dioxide and 1·3 cubic foot of watery vapour; whilst the lighting power of gas per cubic foot depends, of course, upon the particular burner employed.

FIG. 1.—Argand burner.

Speaking generally, there are two principal kinds of burners in use, namely, the Argand and the flat-flame burners. The Argand, in its usual form, is particularly useful for common or low illuminating gas. The ordinary Argand burner consists of a hollow ring, from the upper surface of which the gas escapes by a number of small holes of varying diameters, the most highly illuminating gases requiring the smallest apertures (Fig. 1). In these burners a circular flame is produced, which needs to be protected with a glass chimney, by which the admission of air is regulated. The illuminating power of these burners is that of 30 candles, with an hourly consumption of something like 8·83 cubic feet of gas. For their proper use, a regular and somewhat low pressure of the gas is essential.

Flat-flame burners are of two chief kinds, known respectively as the fish-tail and the bat's-wing. The fish-tail (Fig. 2) consists of an iron nipple perforated by two holes, drilled so that the jets

of gas are inclined towards each other at an angle of 90°. A flat flame is thus produced, and somewhat resembling the tail of a fish. The bat's-wing (Fig. 3) consists of a similar nipple perforated by a fine slit, giving a flat, fanlike flame. In the best forms of all kinds of burners now in use, steatite or pottery (adamas) tops are employed. The common metal and steatite burners in use permit the current of gas to strike against the orifice without any control or regulation, but in the numerous patented forms of both fish-tail and bat's-wing burner, a certain mechanical obstruction or governor is inserted, which breaks or retards the gas current, to ensure more complete combustion. The illuminating power of a good fish-tail or bat's-wing burner equals 16 candles, with an hourly consumption of something like 4 or 5 cubic feet of gas per hour; but the great majority of flat-flame burners in common use of the size known as 4 or 5, and popularly supposed to consume respectively 4 and 5 cubic feet of gas per hour, really

FIG. 2.—Fish-tail burner

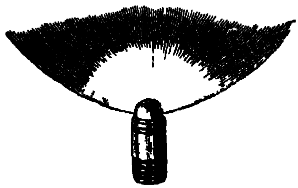


FIG 3 —Bat's-wing burner.

consume nearly double that amount of gas, and at the same time yield an extremely low degree of light.

Assuming the use of ordinary 16-candle gas, the following table gives the illuminating value yielded by ordinary burners for each cubic foot of gas which they consume, as estimated by Professor Lewes:—

Flat-flame No. 4	1·9 candles.
" " 5	2·1 "
" " 6	2·5 "
London Argand	3·3 "
Siemens' Regenerator	10·0 "

The actual products of combustion given off by gas will, of course, vary much with the quality of the gas used and the completeness of the process. The usual products of the combustion of gas are: carbon dioxide, carbon monoxide, compounds of ammonia, watery vapour, and various compounds of sulphur. These latter, if present, are particularly injurious to health, but there is reason to believe that their existence in gas-lit rooms has been much exaggerated. For every 100 cubic feet of gas consumed,

containing 20 grains of sulphur, there would be 0·032 of a cubic foot of sulphur dioxide formed, while with an impurer gas containing 30 grains of sulphur per 100 cubic feet, the sulphur dioxide resulting would amount to 0·048 cubic foot. Except under very exceptional circumstances, ventilation would reduce these quantities in nearly the same ratio as the carbon dioxide, the total volume of sulphur dioxide due to the combustion of the gas being reduced to very minute traces, or something like 0·0625 grain of sulphur as sulphurous acid per 100 cubic feet of air. The presence of undue quantities of sulphurous acid in the air as the result of burning gas is chiefly productive of injury to health owing to the fact that by combining with the moisture and oxygen present in the atmosphere it becomes at once converted into sulphuric acid. This contingency is likely to be of rare occurrence in inhabited rooms, as it cannot take place unless the percentage of water vapour present in the air be at saturation point, an event of most unlikely occurrence.

If we adopt, as is usual, the amount of carbon dioxide yielded as our measure of vitiation of the atmosphere, we find that each cubic foot of gas burnt per hour on an average vitiates as much air as would be rendered impure by the respiration of an individual; for, as has already been stated, an adult exhales 0·6 cubic foot of carbon dioxide per hour, and 1 cubic foot of ordinary gas yields on combustion 0·52 cubic foot of carbon dioxide.

The relative amounts of oxygen removed from the air and carbon dioxide and water vapour yielded by various forms of artificial light in order to give an illumination equal to 16 candles, is given in the following table, in which is also incorporated the number of adults who would exhale the same amount of carbon dioxide in the same time:—

	Sperm candles.	Paraffin oil.	Gas burned in	
			Flat-flame burners.	Incandescent gas-lights.
Amount burnt	1740 grs.	992 grs.	5·5 c. ft.	3·0 c. ft.
Oxygen removed	9·63 c. ft.	6·24 c. ft.	6·50 c. ft.	3·8 c. ft.
Moisture produced	6·56 c. ft.	3·50 c. ft.	7·35 c. ft.	4·6 c. ft.
Carbon dioxide produced	6·56 c. ft.	4·45 c. ft.	3·50 c. ft.	2·0 c. ft.
Air vitiation equal to adults	11·0	7·5	5·0	3·0

If we know, therefore, the amount of impairment and vitiation of the atmosphere produced by one gas-burner, lamp, or candle, it is easy to arrive at the relative contaminating effect which the

various artificial lights produce on the air of a dwelling-room. It follows, therefore, that a system of ventilation designed for a room when no artificial light is used, cannot be expected to be successful when a number of candles, lamps, or gas-jets are burning. Although the contaminations, especially in the case of gas, are very great, it is estimated that for their proper dilution the amount of fresh air supply in relation to the carbon dioxide evolved need not be so great in their case as for breath impurities, a supply of 900 cubic feet of fresh air for every cubic foot of carbon dioxide per hour, evolved by the light, being deemed sufficient, and as every cubic foot of gas evolves 0·52 cubic foot of carbon dioxide, it results that, for every cubic foot of coal-gas burned, something like 450 cubic feet of fresh air should be supplied per hour in addition to those needed to dilute the respiratory impurities.

As judged by the rules already laid down that the vitiation of the air of any limited space, such as a room, is measured by the amount of oxygen used up and carbon dioxide generated, it appears that candles are most injurious to health and comfort, oil-lamps less so, and gas the least of all. Practical experience does not bear this out, since the discomfort and sense of oppression felt by the use of gas in rooms is much greater than that following the use of oil or candles. The explanation of this discrepancy between science and everyday life probably is that, in attempting to light a room with either candles or oil, we are content with much less intense, but a more localized, illumination than when we employ gas. Say we have a room 16 feet long, 12 feet wide, and 10 feet high, and requiring for proper illumination a light equal to at least 32 candle-power. In such a room, if using candles, we should in all likelihood be content with a couple of candles placed near us to read or work, and not place 32 candles in different places to give a diffused yet sufficient light. It is obvious that with only two or three candles we should have less air vitiation produced than if 32 were burning.

Illuminants not only yield actual impurities to the air, but also heat it. The amount of light evolved depends entirely upon the heat generated, simply because much of the light evolved is dependent upon the incandescence or excessive heating of the solid particles of carbon in the flame; and the greater the temperature to which these solid matters are raised the brighter the light. The later researches of Professor Lewes show that excessive saturation of the air and excessive production of carbon dioxide have distinctly deleterious effects upon the illuminating powers of artificial light, though hardly of practical importance in dwelling-rooms.

The more recent improvements in gas-lighting have done much to lessen the vitiation of the air by the products of combustion in dwelling-houses: partly by ensuring a more complete combustion of the gas and partly by arrangements for the rapid removal of their engendered impurities. The former is secured by arranging the burners upon the principle of the Bunsen burner, in which, the gas being mixed with atmospheric air, the combustion is nearly perfect, and consequently no unburnt particles either of carbon or other matter escape unconsumed to foul the air. The incandescent gas-light as now in the market on Auer's system is based upon this principle, the light being derived from the incandescence or glow of a thin veil or mantle of asbestos gauze exposed to a Bunsen flame. This light (Fig. 4) is very brilliant, economical in its consumption of gas, and hygienically sound; its practical defect is its great whiteness and dazzling illuminating power. On the same principle are devised the various forms of inverted or inclined incandescent gas-burners. These are economical in respect both to gas and mantles, and, moreover, in them the gas being thoroughly mixed with the proper quantity of air before entering the burner, more or less perfect combustion is secured with a corresponding increase of illuminating power.

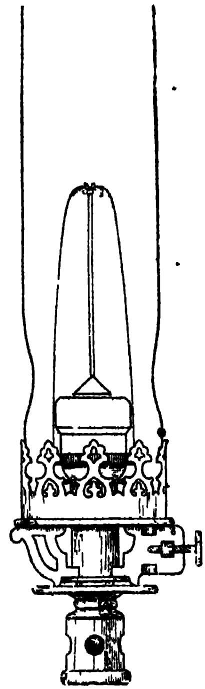


FIG. 4.—Auer's incandescent gas light.

Acetylene has come into some prominence lately as an illuminant. It is derived from the interaction of water on calcium carbide. Compared with ordinary coal gas of 16 candle-power, acetylene shows an illuminating power of 240 candles. Although yielding a very brilliant light, the use of acetylene needs absolute soundness of gas-fittings inside the house, as an escape of this illuminant is liable to be accompanied by grave consequences. When inhaled it acts forcibly and injuriously on the respiratory functions of the hæmoglobin of the blood, and within the limits of 3 per cent. acetylene and 82 per cent. of air may lead to explosions.

Some municipalities and gas companies have taken up the use of so-called "water-gas." This is made by passing steam through incandescent coke or anthracite coal; it is further rendered luminous for lighting purposes by a process known as

"carburetting," in which vaporized mineral oil is added to the gas. Carburetted water-gas has a distinct smell like that of coal-gas, and is usually highly charged with carbon monoxide, which may amount to as much as 35 per cent. The particular danger associated with the use of water-gas is that of poisoning by carbon monoxide, and necessitates the use of most accurately made gas-fittings. Dowson gas is a modified form of water-gas, and presents the same disabilities.

The most hygienic form of light which can be imagined is, of course, the electric incandescent lamp, formed by a thread of carbon or platinum, rendered incandescent by means of an electric current, and enclosed in an hermetically sealed globe without any contact with the air, and consequently quite unable to in any way foul the atmosphere. Unfortunately, these lights are not yet within the reach of every one. The arc electric light, which is not contained in a closed globe, is said to vitiate the air by the formation of nitric acid, but even if so, its effects in this direction are much less hurtful than gas, oil, or candles.

Quantity of Fresh Air needed.—Having now learnt something of the impurities poured into the air of our homes as the result of both respiration and artificial lighting, we have next to learn how much fresh air is required to dilute and remove those impurities, and how best this supply can be attained.

It has already been stated that an average adult exhales or gives off to the air 0·6 cubic foot of carbon dioxide per hour, and since anything below or just up to this amount of carbon dioxide in 1000 cubic feet of air in a room is indistinguishable by the sense of smell from the ordinary outer or pure atmosphere, that limit or amount of carbon dioxide can be regarded as the standard of efficient ventilation. But 1000 cubic feet of pure air contain 0·4 cubic foot of carbon dioxide, therefore they can take up or receive 0·2 cubic foot more of carbon dioxide and not contain an excess over the standard limit of 0·6 cubic foot. The quantity of 0·2 cubic foot of carbon dioxide per 1000 of air, or 0·0002 per cubic foot of air, is commonly spoken of as the *standard permissible impurity*. Based upon these facts, the late Professor de Chaumont suggested a very simple formula to determine the volume of pure air requisite each hour to keep the carbon dioxide in the air of any inhabited room at this limit of 0·6 part per 1000 volumes.

Let **A** be the quantity of carbon dioxide given off per hour per head. Let **B** be the proposed permissible maximum quantity of carbon dioxide in the air of the room per 1000 cubic feet of air. Let **C** be the amount of carbon dioxide present in 1000 cubic feet of fresh air. Let **D** be the amount of fresh air required per head each hour to maintain the standard quantity **B**, expressed in

thousands of cubic feet. Then $\frac{A}{B - C} = D$, or $\frac{0{\cdot}6}{B - 0{\cdot}4} = D$, and if we take B to be 0·6 cubic foot per 1000 of air, we get the formula to read thus: $\frac{0{\cdot}6}{0{\cdot}6 - 0{\cdot}4} = D$, or $\frac{0{\cdot}6}{0{\cdot}2} = 3000$ cubic feet of air needed each hour per head.

If it be the case of an individual doing light work in a room, and giving off say 0·95 cubic foot of carbon dioxide per hour, we should have A = 0·95, and the formula stands as $\frac{0{\cdot}95}{0{\cdot}6 - 0{\cdot}4} = D$, or, in other words, D would equal 4750 cubic feet of fresh air required hourly in order to keep the impurity down to the standard limit.

The formula can be used in another way. Suppose the air in a room has been found to contain 1·2 volume of carbon dioxide per 1000—that is, 0·0012 per cubic foot of air—and it is required to know how many cubic feet of fresh air have been hourly delivered per head. In this case, the actually observed air impurity, namely, 1·2, takes the place of the maximum permissible impurity; that is, B now equals 1·2, hence we get $\frac{A}{B - C} = D$, or $\frac{0{\cdot}6}{1{\cdot}2 - 0{\cdot}4} = D$, or $\frac{0{\cdot}6}{0{\cdot}8} = D$. That is, 750 cubic feet of air have been actually delivered per hour in the room.

By a transposition of the same formula we can calculate the probable condition of the atmosphere of a room into which a given quantity of air has been or is being supplied. The formula would then stand thus: $\frac{A}{D} + C = B$. If in a room containing 5 persons, each giving off 0·6 cubic foot of CO_2 hourly, we assume 1500 or 1·5 thousand cubic feet of air to have been supplied per hour and to represent D, we get $\frac{5 \times 0{\cdot}6}{1{\cdot}5} + 0{\cdot}4 = B$, or $B = 2{\cdot}4$; that is, 2 parts of carbon dioxide per 1000 of air will be present in the air of the room over and above what is normally present in the outer air. In some cases, of course, A would not be represented by 0·6 cubic foot, as say, in the case of an adult man doing hard work; the amount of carbon dioxide given off by him per hour would be as much as 1·96, or nearly 2 cubic feet, and in the case of children, might be as low as 0·4 per hour. The general statement, however, of the formula remains the same.

A consideration of these facts indicates that if we wish to keep the air of our homes at the standard degree of purity, it should not contain more than 0·6 part of carbon dioxide in 1000,

or 0·2 part in 1000 over the average in samples of ordinary air. Further, in order to keep the carbon dioxide below 0·6 part per 1000, it is necessary to change the atmosphere by supplying fresh air, and this, as worked out, means a supply of 3000 cubic feet of fresh air every hour for each person. The following table gives the amounts of carbon dioxide given off by various persons per hour under varying conditions, and, corresponding to them, the quantities of fresh air theoretically needed under those circumstances to maintain the air at standard purity :—

	CO_2 given off per hour in cubic feet.	Fresh air needed hourly per head in cubic feet.
Adult male in very hard work	1·96	9800
„ „ in light work	0·95	4750
„ „ at rest	0·72	3600
Adult female at rest	0·60	3000
Children	0·40	2000
Average of a mixed community	0·60	3000

Carnelley, Haldane, and Anderson, basing their opinion not only upon the average presence of carbon dioxide in the air, but also upon the organic matter and number of micro-organisms, proposed that instead of taking 0·6 cubic foot of carbon dioxide per 1000 as the limit, that the standard should be 1·0 for dwellings and 1·3 for schools. In the case of organic matter, that not more than two volumes of oxygen should be required for oxidation per million volumes of air, and that the micro-organisms should not exceed 560 per cubic foot of air.

In mines as much as 6000 cubic feet per hour have been proposed to ensure maximum energy in those working below ground. In hospitals and for the sick generally, the maximum amount of fresh air ought to be at least one-fourth more than that allowed in health. If 3600 cubic feet per hour be accepted as a general average supply for health, we may admit the needs of the sick to be at least 4500 cubic feet per hour.

As regards the amount of fresh air required for animals, the following table gives theoretical quantities of air as worked out by various observers :—

	Cubic feet per head per hour.	Cubic feet of space.
Cows	8000	1600
Calves	3000	600
Horses	8000	1600
Dogs	500	100
Pigs	3500	700
Cats	400	80

It is probable that these amounts are too small; at least 25 cubic feet per pound of body weight ought to be supplied, as,

like human beings, all animals thrive best in well-ventilated places.

Cubic Air-Space required.—Though theoretical considerations may indicate that certain quantities of fresh air are needed per hour per head in order to maintain the atmosphere at a degree of sweetness compatible with health, yet when it comes to actual practice, certain difficulties are met with. Experience shows that under the ordinary climatic conditions of this country, the air of a room cannot be changed more than three times an hour without causing much inconvenience by draught. This means that if we are to have 3000 cubic feet of fresh air each hour, we must each have a cubic air-space of at least 1000 cubic feet. If it be less than this, say, 100 cubic feet of space, then in order to deliver 3000 cubic feet of air hourly, the renewal of air will have to be thirty times in that period of time, and this we know, owing to the formation of draughts, would be unbearable unless the incoming air be warmed. At 60° F. air, moving at the rate of two feet per second, is barely perceptible; at three feet it is more so; and above this it becomes a draught. At 70° F. the velocity of the air-current can be even greater without being noticed. The question arises, what then is the least amount of cubic space through which the standard quantity of fresh air can be passed without causing inconvenience from draught? By experiments made with the best mechanical means and artificial heat, Pettenkofer determined that in an air-space of 424 cubic feet, 2640 cubic feet of air could be drawn through in an hour without perceptible draught; this was equivalent to a change of air at the rate of six times an hour. But in ordinary circumstances, and without artificial methods of warming the incoming air, a renewal of air in a room at the rate of six times an hour in this climate could not be tolerated. In fact, a change of air three or four times an hour is about as much as can be borne, and this brings us to an original air-space of close upon 1000 cubic feet. Whatever the amount of air required hourly per head, the cubic space per head should be in the proportion of one-third this amount. The moment we attempt to ventilate a small space, say 500 cubic feet, by ordinary or so-called natural means of ventilation, the difficulties arise not so much from the actual rate of movement of the general mass of air, as from the velocity with which the air enters at the openings and the nearness and relative position of these to the persons occupying the space. In order to supply 3000 cubic feet per hour, in each minute $\frac{3000}{60} = 50$ cubic feet must enter, and in each second $\frac{50}{60} = 0{\cdot}83$ cubic foot. If the inlet opening be a square foot, the velocity of a current that would introduce 0·83 cubic foot would

of course be 0·83 linear foot per second. Taking a room with 3000 cubic feet of air to be delivered per hour, and having an inlet or opening of 12 square inches, the rate of movement of the incoming air would be 10 feet per second, or nearly seven miles per hour; the room being so small, the rapid current of air could not be broken up, diffused, and mixed with the larger mass in the chamber sufficiently before striking its occupants and giving rise to a feeling of draught. If, of course, the room were just double the size, say 1000 cubic feet, or the apertures of inlet be enlarged, the movement would be less felt; but if the space be small, say 500 cubic feet, any enlargement of the inlets renders them altogether too large in proportion to be practically allowable.

Even with some artificial arrangements, experience goes to show that in small spaces the air becomes much more impure than in large ones; the reason being that in small spaces, even if large quantities of fresh air are being supplied, little uniform diffusion occurs, as owing to the frequent establishment of direct currents between inlets and outlets, large amounts of the fresh air escape without being made use of; also that in small spaces ventilation gets stopped much more readily than in larger ones, and if this occur, the ratio of increase of impurities is far greater in the small rooms than in the larger.

The amount of air-space which these theoretical considerations indicate ought at least to be given to each adult, appears to be not less than 1000 cubic feet, but this is undoubtedly much in excess of what most people are able to get. Excellent as is the standard laid down by de Chaumont, prolonged experience shows it to be practically impossible of attainment in this country under ordinary circumstances. We, therefore, are disposed to accept the standard limit suggested by Carnelley as being one most likely to meet ordinary conditions. If we take that as being a maximum of 1·0 cubic foot of carbon dioxide per 1000 cubic feet of air, we get a permissible respiratory impurity of 0·6 in place of 0·2 cubic foot as suggested by de Chaumont. This means a need of 1000 cubic feet of fresh air each hour in place of 3000, and assuming that the necessary change of air cannot be made oftener than three times an hour, we find the minimum air-space for each adult will then stand at about 350 cubic feet; this we find to be closely in accord with present-day conditions. For humified weaving-sheds and workshops, the regulations of the Home Office permit a maximum of 9 volumes of carbon dioxide in 10,000 of air when no gas is burning. This means a permissible respiratory vitiation of 0·5 per 1000 of air. A recent departmental Committee, dealing with the same subject, has gone so far as to recommend an increase of permissible CO_2 to 12 volumes by day

and 20 by night with gas burning, for every 10,000 volumes of air. We confess to grave doubts whether this reduction of ventilation standards in places of this kind is wise, though we are fully alive to the difficulties in the way of securing the lesser degrees of vitiation as laid down by earlier writers on the subject.

In the majority of rooms occupied by the poorest classes, the cubic space available for each occupant is rarely more than 250 cubic feet, while in the lodging-houses of the larger towns the allowance is not more than 300 cubic feet. In elementary schools the regulation minimum allowance is 100 to 120 cubic feet per head. In factories and workshops, 250 cubic feet of air-space are required per head during the day, and 400 cubic feet during overtime. For soldiers in barracks, 600 cubic feet is the least space allowed. In hospitals, the cubic space ought to be quite 1500 cubic feet, if not nearly 2000; and the minimum floor-space 100 square feet. In all rooms with more than one occupant, it is necessary that a certain floor-space should be allotted to each person, for the purpose of allowing currents of air to remove emanations from one individual without interfering with his neighbour. For this reason, in all cases, whether private houses, barracks, hospitals, or other public buildings, a good rule is to secure as the lowest limit of floor-space an area not less than one-twelfth of the cubic space. Moreover, it is important to remember that mere height in a room is of no advantage unless combined with means for removing the heated air from the upper part, and that mere cubic space cannot take the place of change or renewal of air, for even the largest of air-spaces can only supply sufficient air for a limited time, after which the same amount of fresh air must be supplied. This 350 cubic feet of space for one adult would be sufficient if the air in it were changed three times an hour, but in the absence of any renewal, 350 cubic feet of air would only be sufficient for one person for 20 minutes. Of course, it must not be overlooked that the source from which supplies of fresh air are drawn must be pure; and that, notwithstanding the fact of the standard quantity of air being delivered hourly per head, no claim could be made in such case for the existence of proper ventilation if the incoming volumes of air were in any way derived from contaminated or impure sources. In a similar way, attention needs to be directed to the actual temperature of the air entering a chamber; in summer it may need to be cooled as much as it requires to be warmed in winter, the reason being that the actual temperature of an air-current is the main factor in our appreciation of its velocity. Owing to the fact that expired or foul air is warmer and lighter than pure air, it tends to rise to the upper parts of a room, for which reason, to ensure free ventilation, the outlets for

impure air should be at or near the highest point, and the inlets, arranged so as not only to avoid draughts blowing upon the occupants, but also to secure equal diffusion of the air, should all be given an upward direction, whereby the tendency of the fresh masses of air, particularly if cool, to fall to a lower level, is minimized as far as possible.

We have already defined ventilation as the removal or dilution, by a supply of pure air, of all the impurities which can collect in the air of inhabited rooms or houses. The next matter which demands consideration is how the ventilation of a room can be secured. It is usual to class the different methods of securing ventilation under two general heads: they are, the *natural* and the *artificial*. Now, all the methods of spontaneous diffusion produced by the unequal density of two columns of air, whether caused by chimney draughts or otherwise, belong to the former class; while the various methods of ventilation by means of pumps, fans, bellows, and various other contrivances, belong to the latter. The principles which bring about both these methods of ventilation are not difficult to understand, being based upon the action of well-known physical laws, all of which were discussed when we considered the physical properties of air.

Natural Ventilation.—This is carried on by the simple agency of gaseous diffusion, winds, and the movements of air caused by inequalities of temperature. We have seen that every gas diffuses at a rate which is inversely proportional to the square root of its density, and that while two gases of the same density show little tendency to mix, two other gases of different weights or densities would intermingle with great rapidity. For this reason, the air of rooms, being usually warmer than that outside, diffuses with rapidity through cracks and openings, and even through porous materials, such as sandstone, bricks, mortar, and mud. To such an extent is this the case that experiments have shown that with a brick-and-mortar wall, a room containing 2700 cubic feet of air has its entire contents changed in an hour when the inside temperature is 65° F. and the outside just freezing. The amount of interchange between the inside and outside airs of rooms, rapidly lessens, the more the temperature of the inside and outside agree one with the other; this explains why a room is often better ventilated in winter during a frost, with all its windows and doors shut and with a good fire in the grate, than in summer, with the windows wide open, and the inside and outside temperatures nearly identical. As a ventilating power, diffusion alone is found to be inadequate, mainly because all air impurities, as we know, are not gaseous, but partly molecular, and, as such, not affected by it.

The action of winds, as an agent in the production of natural ventilation, is partly by what is called perflation, and partly by aspiration. The wind is said to perflate if it pass freely through open doors and windows into a room; its ventilating action then is immense, but much less so if a thorough current cannot be obtained, as in narrow courts and alleys, or when pieces of furniture, curtains, etc., block the way. Mention has already been made of the ease with which air can pass through bricks, etc., but the action of the wind in this respect is probably not so powerful as generally believed. The ventilating power of winds by mere perflation is irregular, owing to the uncertainty of the air movements.

As illustrating the great aspirating power of the winds, as a ventilating agent, we may refer to the fact that winds blowing over the tops of chimneys or tubes cause a current of air to flow at right angles to themselves up the chimney or tube (Fig. 5); at the same time a similar wind can and does impede ventilation by either blowing against some opening or down a chimney. This reverse action can, of course, be obviated by placing a cowl or other similar contrivance on the top of the chimney. Many schemes of ventilation fail owing to their having been designed with too little regard to the diversities of wind force and direction.

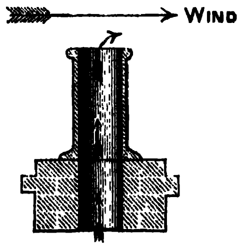


FIG. 5.—Draught up the chimney caused by the wind blowing over the top.

The primary force, which produces not only winds but the movement of all bodies of air, is the difference in their weights or densities due to inequalities of temperature. If a column of air contained in a tube or chimney be heated, it expands according to the ascertained law of Charles, which we have learnt is applicable to all gaseous bodies. This law, which regulates the movements of the air in any confined space, like a chimney or tube, when its temperature is higher than that of the outside air, depends really upon the following considerations: (1) Upon the difference between the temperature of the inside and outside airs. (2) Upon the area and other conditions of the openings through which warmed air can flow out and the cooler air flow in. (3) Upon the height of the ascending column of warm air.

If a column of air, say in a chimney, be 10 feet high, and have its temperature raised by a fire in the grate below, 20° F. above that of the air outside the chimney, then it will expand, for reasons already explained, $\frac{20}{491}$, or as near as possible $\frac{1}{24}$ of its bulk; as a result its specific gravity or density would be

lessened, and it would require to be $10\frac{10}{24}$ feet or 10 feet 5 inches high to balance a column of the outer air 10 feet high when the temperature of the latter is 20° F. lower than the former; but as the height of the warmer column is exactly that of its containing chimney, which is only 10 feet high, the colder or outer column of air presses it up with a force proportionate to their difference in weight, and with a velocity equal to that which would be acquired by a body falling through a space equal to the difference in height that the two columns would occupy, if of equal weight, which in this case is 5 inches or 0·4 foot.

Now, by an application of the combined laws of gravity and the acceleration of forces, we are able to express the velocity in feet per second of a falling body by the formula $V = \sqrt{2gh}$, in which g is the velocity given to a falling body by the accelerative force of the earth's gravity; this, in our latitude, is 32·2 feet per second; h is the height through which the body falls. This formula, $V = \sqrt{2gh}$, which is sometimes called Montgolfier's formula, will then stand or read, $V = \sqrt{2 \times 32{\cdot}2 \times h}$; but that portion of the formula $\sqrt{2 \times 32{\cdot}2}$ equals 8·2, or practically 8. Hence, we can simplify it and write $V = 8\sqrt{h}$, or say the velocity of the falling body equals eight times the square foot of the height it falls. In the case we have supposed, 0·4 foot is the height of the effective descent or fall of the heavy column of colder air; hence, applying Montgolfier's formula, we can say $8\sqrt{0{\cdot}4} = 5{\cdot}056$ feet per second, or 303 feet per minute, will be the velocity with which the heated column of air would be drawn up the chimney. Very often in its application to ventilation problems the whole calculation is expressed by the formula being written thus—

$$V = \sqrt{2ga(t' - t)h},$$

in which the other symbols remaining as above, a is the coefficient of the expansion of air for each degree of temperature, t' the temperature of the heated column of air, and t that of the colder.

Having ascertained the exact velocity of the air-current, this, multiplied by the area of inlet, gives the cubical amount entering the space. Supposing, in the above example, the opening or throat of the chimney were one foot square, there would pass out or up that chimney 303 cubic feet per minute. This rate of flow is, however, subject to certain corrections, chiefly in consequence of friction arising from angular deviations of the chimney or tube. In straight tubes, the friction is found to be in all cases directly as the length of the tube and inversely as the diameter. In general practice, a deduction of from one-fourth to one-third of

the velocity is necessary to compensate for these influences, and to obtain a true rate of outflow.

There are various other ways of determining the direction and velocities of air-currents. Thus, by noting the direction of smoke caused by burning pieces of velvet; by floating hydrogen balloons so weighted as to be of the same specific gravity as the air; or, if such be available, by means of an anemometer. This latter is a very delicate instrument, consisting of four vanes attached to a spindle, the revolutions of which are recorded on a dial. If placed in an air-opening about $\frac{2}{5}$ of the diameter from the side, so as to obtain the mean velocity, the vanes are turned by the direct action of the air-current, and the velocity calculated from the linear movement as recorded on the dial-plate during some given period of time; this, multiplied by the sectional area of the opening, gives the cubical delivery or discharge according as to whether it be an inlet or an outlet. The actual velocity of air as it flows in and out of a room should not exceed one or at most two feet per second, simply because a low velocity is favourable to uniform diffusion of any incoming air through the room, and because a high velocity is apt to give the sensation of a draught. As explained, some allowance must be made for friction, particularly in outlets, and here the velocity should not exceed 3 to 5 feet per second. The particular velocity in any given case will naturally be regulated by the sizes given to the inlets and outlets, and on the quantity of air needed as indicated by the precise number of occupants, the amount of artificial lighting, and other special causes of air vitiation.

Having in the preceding pages learned something of the general laws and circumstances which govern the movements of air, as well as considered the amount of air to be provided, it is necessary now to discuss the various methods which have been adopted or proposed to practically apply them. Of all the methods of natural ventilation, the simplest and most obvious is that of more or less open doors and windows; but this arrangement, except in the warmest summer weather, causes draughts, and is unpleasant. To secure adequate perflation, all windows should, if possible, be placed on opposite sides of a room, while, too, each of such windows should be made to open at the top. Owing to air flowing against the body, at or even slightly above the temperature of a room, causing a sensation of cold or draught, it is necessary for comfort that air should be introduced and removed from inhabited rooms at those parts where it will not give rise to a sensible draught. In a large majority of houses, particularly those of the poorer and middle classes, even in these days, ventilation arrangements are either of the most crude and

haphazard kind, or else absolutely wanting altogether. The greater number of living-rooms depend for their supply of fresh air upon just so much as can find its way in through doors, windows, or through cracks and crevices around and under doors and windows, or even through the floor, and for the escape of foul air, upon what goes up the chimney, if a fire be alight, or what can get out through doors and windows; the general result being that either the chamber is so cold and draughty that no one can live comfortably in it, or so hot, close, and stuffy, that health is affected.

All ventilation methods aim at avoiding these results, by providing, in the first place, inlets, or means of entrance for the fresh air, and outlets, or means of escape for the foul or impure air. It will be readily understood that all *inlets* or orifices by which cold fresh air is admitted should be above the level of the heads of those occupying a room, say 9 feet, and directed upwards to the ceiling, while the actual current itself should be as much broken up or dispersed as possible by means of trumpet-shaped openings, the smaller apertures of which are towards the outer air and the wider towards the room. If the inlets be intended for delivering previously warmed air, then they should discharge near the floor. The warming of air previous to its entering a room by an inlet is conveniently done, either by the use of an air-chamber placed behind a grate or stove, as in Galton's stove, or by the passage of it over hot-water pipes.

As to *outlets*, since the escaping impure air is invariably warmer than the incoming or fresh supply, the right place for them is the top of the room, and in cases where the foul air is specially warmed, as over ventilating gaslights, the connection of the outlet tube with the chimney constitutes the best arrangement. In all cases, these structural devices, whether as inlets or outlets, should permit of their being kept free from dirt or otherwise getting blocked up.

Among the many devices for inlets of fresh air is the simple plan, suggested by Hinckes Bird, of raising the lower sash of a window by an accurately fitting block of wood, whereby a corresponding space is left between the meeting-rails in the middle of the window, through which entering currents of fresh air are directed up towards the ceiling (Fig. 6). With the same idea, others have proposed double panes of glass, an open space being left at the bottom of the outer and at the top of the inner one. Similarly, a pane may be louvred, that is, strips of glass lying one over the other, and fixed on to a frame, which, by means of a lever, can be opened or shut at will (Fig. 7). Windows can be so made that, when they open, they slope into the room, or they

can have a part of a pane to open or shut by a spring, as in Boyle's or Cooper's ventilator (Fig. 8).

An excellent form of inlet is that known as Sherringham's valve (Fig. 9), which consists of an iron box so made that the air enters from outside through a perforated brick or grating, and is directed up towards the ceiling by means of a valve which can be made to close or open by means of a balanced weight. The inside

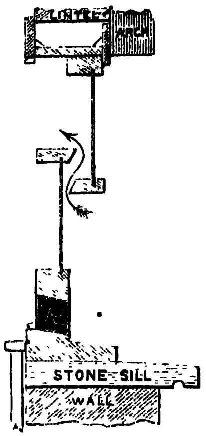


FIG. 6.—Hinckes Bird's plan of window ventilation.

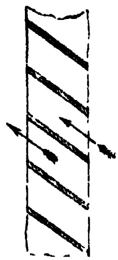


FIG. 7.—Louvre ventilator.

area of the ventilator is larger than the outer, consequently the air enters the room at a less velocity than at which it passed through the outer wall or grating. Another plan, advocated originally by Tobin of Leeds, is that of introducing the air through horizontal shafts under the floor, and then delivering it

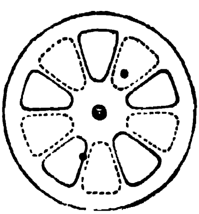


FIG. 8.—Cooper's ventilator.

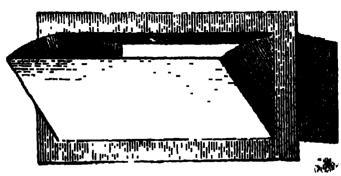


FIG. 9.—Sherringham valve.

into the room through vertical tubes (Fig. 10), at different heights, varying from 6 to 9 feet from the floor. The currents of air issuing from these tubes ascend and then curve imperceptibly downwards. For public buildings, like churches or halls, the columns which support galleries may on this principle form convenient inlet tubes. These Tobin tubes are not very suitable

for ordinary houses and dwelling-rooms, as they are difficult to keep clean, and often become clogged up by cobwebs, dirt, and dust. They, moreover, do not readily become or act as outlets when occasion requires, which, being a conspicuous feature of the Sheringham valve, renders that form of ventilating agent practically the most convenient for everyday application.

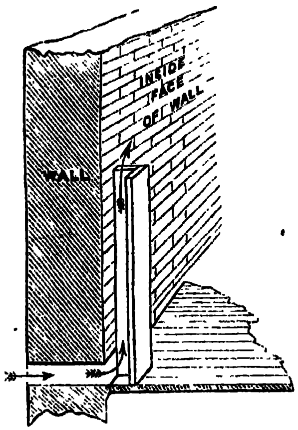


FIG. 10.—Tobin's ventilating system.

Suitable inlets can be provided by what are known as air-bricks, of which probably the best types are those of Ellison and of Jennings. They are merely specially prepared bricks perforated with a number of holes, so cut that the inner aspects of the perforations have a larger diameter than the outer, whereby the velocity of the entering air-current is lessened. The wind blows through them, but with a variable movement. In Jennings' air-brick, the perforations are directed upwards, so that the entering air-current flows rather towards the ceiling than down towards the floor.

With all or any of these simple ways of letting fresh air into rooms, it is presumed that equal facilities are offered for the escape of the foul air. In most rooms, particularly if a fire be alight, this will be done largely by means of the chimney connected with it, but in its absence may need be accomplished by special outlets. The simplest form of outlet, other than a chimney, is a special shaft from the ceiling to above the roof; this is the principle adopted in the army for ventilating barrack-rooms and hospitals, combined with arrangements for admitting warmed air. The movement of air up such an outlet shaft will largely depend upon the aspirating action of the wind over its top, and upon the particular temperature inside it as compared with that of the outer air. Owing to the uncertain and disturbing action of these influences, these shafts do not always act as outlets, but in any case facilitate a continuous change of air, whichever way they happen to act. Down currents in such shafts can usually be obviated by placing a cowl or valve on its upper orifice, or by leading it up inside a chimney.

Frequently so-called ventilating gaslights are used as outlets, in which the products of combustion, after being collected by means of a cover or bell-glass, are carried off by a tube which is

itself often contained in a larger one. Owing to the heating of the inner tube, the space surrounding it and between it and the outer one acts as an extracting-shaft for foul air. In theatres and other public buildings, advantage is taken of this method by using the Sunlight gas-burners (Fig. 11), which, in addition to lighting the building, act as extraction-shafts for removing the polluted air.

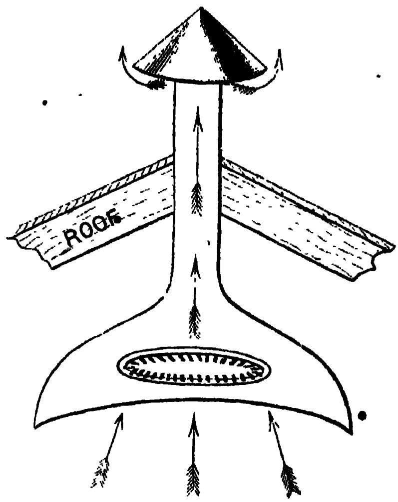


FIG. 11.—Ventilation by Sunlight gas-burner.

Another arrangement, known as Arnott's valve (Fig. 12), is designed to act as an outlet for foul air. It is usually placed in the wall of a room near the ceiling, so as to open into the chimney. The valve is so arranged as to swing towards the chimney, when the pressure or draught of the air is from the room to the chimney; but when the pressure is greater from the chimney to the room the valve closes, and thus prevents the escape of smoke or air from the chimney into the room. These valves are sometimes objectionable owing to the noise they make.

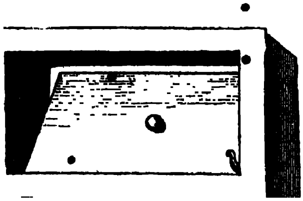


FIG. 12.—Arnott's valve.

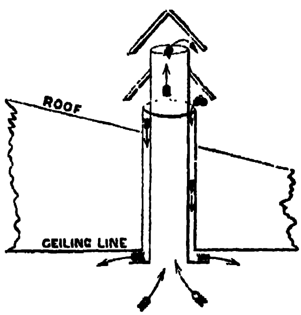


FIG. 13.—McKinnell ventilator.

An ingenious ventilator is that of McKinnell's (Fig. 13), which consists of two tubes, one inside the other, carried up through the ceiling of a room; fresh air passes down in between the two tubes, and by a flange on the inner tube is dispersed. The inner, or outlet tube, which is always made sufficiently large to equal in

area the inlet, projects well beyond the other, both above and below, and effectively carries off foul or impure air. This is a very useful method of ventilation under certain conditions, but, like all others, is not universally applicable. On much the same principle, ventilating cornices are made, which consist of a double channel of perforated metal: by the lower channel cold fresh air is brought into a room, while by the upper one the fouled air is carried to the chimney or other outlet. Analogous to this plan is that of carrying along the cornice of a room, on three sides, a perforated inlet tube, while on the fourth side is a similarly perforated outlet tube.

In other cases, by a like contrivance a fairly good cross-ventilation can be secured by means of a series of transverse ventilating boxes or tubes placed at regular intervals and close to the ceiling. These, running across the room from wall to wall, open into the outer air at each end by an air-brick. The sides of these tubes are made of perforated zinc, and to prevent the wind blowing right through, they are stopped or blocked in the centre by a partition. According as to whether the wind blows from one side or other, so one half becomes an inlet for fresh air, which diffuses gently into the room through the perforations, while the other half acts as an outlet for the fouled air.

As regards the size of inlets and outlets, the conditions of temperature are so variable that it would be impossible to fix on a size that should be universally applicable; as an average for this country a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt. As a rule, the size of these openings should be in proportion to the size of the room; it is better to have openings too small than too large, and while the inlets and outlets can be usually of the same size, still no one individual inlet ought to be larger in area than 60 square inches, nor an outlet more than 144 square inches.

Artificial Ventilation.—For the production of artificial ventilation, two systems are in use: namely, ventilation by extraction and ventilation by propulsion.

The simplest example of ventilation by *extraction* is the action of an ordinary fireplace, which, by heating a column of air, causes its expansion, ascent, and replacement by another but colder volume. The ventilation of theatres is largely carried out by utilizing the central chandelier and all the gas-jets, which being each placed under outlet tubes, by warming the vitiated

air, cause it to expand and escape up the tubes, which are so arranged as to all unite and empty themselves into a single large outlet, thus serving to carry off the products of both respiration and combustion. Mines are largely ventilated by means of a furnace at the foot of the upcast shaft, its supply of air being drawn down another shaft and then made to pass through all the workings on its way to the upcast by an ingenious arrangement of doors and partitions.

As typical of the various methods proposed for ventilating artificially large buildings, by means of extraction, may be

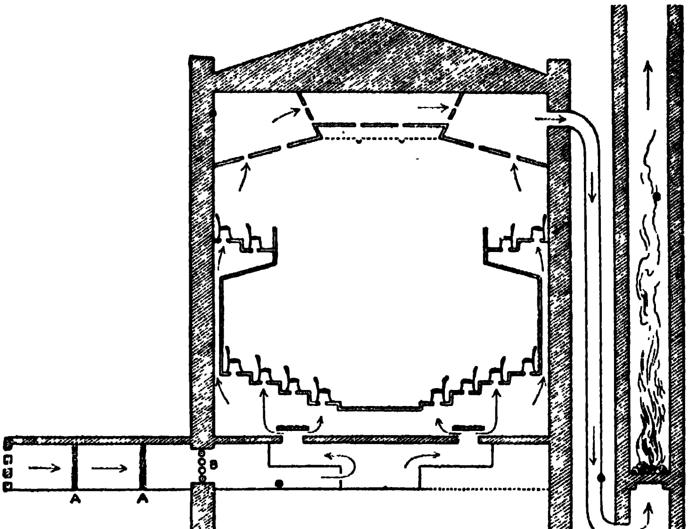


FIG. 14.—System of ventilating the Houses of Parliament.

mentioned the system of ventilating the Houses of Parliament, and that of Jebb for prisons. In the case of the Houses of Parliament, fresh air is made to enter the basement, where it is first washed or filtered through screens (A, A) of moistened canvas, then passed over steam-pipes (B), by which it is warmed, and next conducted by shafts to spaces beneath the floors and benches of the rooms. The vitiated air ascends to the roof or ceilings, through which it passes by perforated openings, and is thence conducted by a shaft down to the basement of the clock-tower, where the flue of a furnace furnishes a powerful up-exhaust (Fig. 14). The power of the clock-tower exhaust is so great as to act equally

well when the incoming air is not heated, but even actually cooled, as it is in summer.

Jebb's system for prisons consisted really of the extraction of the foul air near the floor of the cells, and its admission at the ceilings. The idea was that fresh air entering the basement is warmed by hot-water pipes; from there, by means of separate flues, built in the inner walls of the corridors, it ascends to each separate cell by an opening near the ceiling, while the foul air escapes or is sucked out near the floor level, and made to ascend, by other flues, to the ridge of the roof. Its ascent is aided by a current of hot air from fires kept burning in the roof, and which, coupled with the current from the basement fires, exerts a very powerful up-draught. The great objection to this system was that it was expensive in the consumption of fuel.

In the Bank of England, the cellars are ventilated in a somewhat similar way, the up-draught being kept going by means of gas-jets burning in the flues of chimneys or special shafts. Perhaps the most elaborate and complete system of artificial ventilation for a private house is that of Drysdale and Hayward, of Liverpool. In principle it is very similar to that in the Houses of Parliament, the kitchen being placed in a position to act just as the furnace in the clock-tower, and is, in fact, the only fire kept constantly burning. Of course, it will be readily understood that any such scheme as this is only feasible in compound buildings or residences of exceptional design, and, to be carried out economically and well, must be thought of while the house is being built, and not after it is built and finished.

On board steamships, a similar plan is arranged, the upcast being a space round the boilers and funnel; and while a strong current of air rushes up this space, air to feed it is directed down the hatchways. The same method is turned to account in hotels and public buildings by the utilization of hot-water pipes to cause currents of air in suitable extraction-shafts.

As aids to extraction methods, various forms of cowls have been invented, but no one of them can be recommended as being absolutely successful. More successful is extraction by fans. A paddle-wheel-shaped fan, inclosed in a chamber, is placed in the roof of a building and conveniently driven by a gas-engine. By the revolutions of the fan, the foul air is drawn up from the apartments through ventilators placed near the ceiling into tubes, and by them conducted to an open-air outlet above the fan. Fresh-air inlets are of course provided near the floor levels of the room so ventilated.

In the case of ventilation by *propulsion*, the air is driven

mechanically by either bellows, pumps, or fans into proper channels. This plan of artificial ventilation is more adapted for factories and workshops than for ordinary houses. In the former, besides for ordinary ventilation, currents of air are often required to blow away dust or suspended matters, for which purpose the openings need to be near the floor and not near the ceilings, as for ordinary vitiated air. Strictly speaking, what is called the propulsion method is an impulsion system, as by it fans are used to propel air into a basement chamber, from whence, after being heated over coils of hot-water pipes, it is carried by ducts to each room separately. These ducts open some 7 feet above the floor level, and as the velocity of the impelled air is considerable, it is diffused near the ceiling, and moves down through the room imperceptibly, to finally escape at the floor into vertical outlet shafts discharging at the roof.

Though much less common than extraction methods, ventilation by propulsion has the advantage of precision and ease and certainty with which any given volume or required volume of air can be treated or used; it, however, is expensive. Owing to the absence of control over the sources from which air is sucked in extraction methods, due to the readiness with which air rushes in at all available apertures, the supplies of air under these circumstances are occasionally drawn from objectionable places. With care, however, provision can be made to either warm, cool, wash, or filter the air at suitable points.

On the whole, the advantages of artificial ventilation are great, being mainly due to its facility of management and constancy under varying conditions. For factories, workshops, ships, and wherever there is machinery, artificial ventilation, whether by extraction or propulsion, is certainly the most economical and convenient. On the other hand, public buildings, such as prisons, theatres, and hotels, commonly require to be ventilated by some mechanical arrangement based upon the utilization of all fires and gas to work an exhaust-shaft. In private houses, the use of ventilating grates and stoves, or some of the simpler plans of ventilation, should suffice to keep the air pure, but no hard-and-fast rule can be laid down, each case requiring to be considered intelligently on its merits.

Warming and Heating.

This subject is very closely connected with ventilation, but for its thorough comprehension some knowledge is necessary of the laws of heat. Now, heat is distributed in three ways: these are by radiation, by conduction, and by convection.

Radiation of heat is not only the most common but the most wasteful. This kind of heat is propagated in straight lines in all directions with equal intensity, the effect lessening according to the square of the distance; thus, if the heat at one foot distance from a fire be 1, then at ten feet it will be one hundred times less. If radiant heat fall on a solid body, it is reflected in the same way as light, but some of the heat is absorbed, the amount reflected and absorbed being in inverse proportion to one another, and largely dependent upon the surface, colour, and nature of the body.

Heat is **conducted** through all solids, but to a very limited degree only by liquids and gases. The best heat conductors are the metals, then stone, next wood, and least of all wool or silk. Bodies which are good conductors rapidly give off their heat to the surrounding air or to anything in contact with them; in like manner, if colder, they withdraw heat from other bodies. Porous materials, like felt, are extremely bad conductors of heat.

The **convection** of heat is that mode in which heat is propagated in liquids and gases, and is dependent upon that characteristic of those bodies which allows the portions of them which have been heated to expand and rise, their place being taken at once by colder parts. A sort of circulation of the water or air is set up, and the whole mass soon warmed.

Disregarding any particular variations in the source of heat, that is, whether from coal, coke, wood, etc., we can say that the principal methods of warming and heating houses or rooms may be classed as either open fires, closed fires or stoves, and pipes containing either heated air, hot water, or steam.

Open Fires.—Long-established custom and prejudice have caused open fires to be the means of heating nine-tenths of the houses in England, notwithstanding the fact that they are really the most costly and imperfect means of heating, as evidenced by the fact that they only render available 13 per cent. of the total heat capable of being yielded by coal or coke, and only 6 per cent. of that by wood, the rest being lost in the air, or escaping as unconsumed carbon up the chimney. The actual heating effect of open grates is most unequal in different parts of a room, but on account of the cheerful light which they emit, and the ventilation which they ensure, open fires will always be preferred as the pleasantest and healthiest mode of heating. Following Teale, the chief practical points to be aimed at in making open fireplaces, may be summarized as follows:—(1) Use as little iron, but as much fire-brick, as possible. (2) The back and sides should be made of fire-brick. (3) The back of the fireplace should lean or hang over the fire, while the throat of the

chimney should be contracted. (4) The bottom of the fire should be deep, from before back. (5) All slits in the bottom of the fire should be as narrow as possible. (6) The bars in front should be narrow. (7) The space beneath the fire should be closed in front by a close-fitting iron shield or "economizer." The object of this latter point is to secure as complete combustion as possible of the fuel at the bottom of the fire by the exclusion of cold air. In the use of an ordinary open fireplace, about one-eighth of the heat given off by the fuel consumed is utilized on the air of the room. All open grates should be made so as to have the fuel slowly and completely consumed, while the draught up the chimney should not be in excess of ventilation requirements. Most English grates consume 8 lbs. of coal in an hour: for the combustion of each pound of coal 300 cubic feet of air are needed; this means 2400 cubic feet hourly, but in actual practice something like 20,000, or even 40,000, cubic feet of air pass up the chimney; in which case, supposing the room contains 4000 cubic feet of space, the air in it gets changed from 5 to 10 times in the hour according to the strength of the fire. If the incoming air were warm, this liberal ventilation would be excellent; but, unfortunately, it rarely is so, but is in the main quite cold, finding entrance through the floor, or by chinks round the windows or beneath the door.

Stoves, as usually made, are of cast iron, and are essentially apparatus for heating with a detached fire, so placed that the products of combustion escape by an iron flue or chimney to the outer air, while the main portion of the generated heat radiates in all directions round the stove. At the lower part is usually a draught-hole, by which the air necessary for combustion enters. Owing to the less waste of heat by these means of warming than by open grates, this mode of heating is the more economical, but by no means so healthy as that by ordinary fireplaces, because their ventilating power is so much less. Stoves are often objectionable owing to their making the air hot and dry, but this can be obviated usually by placing vessels of water upon them. They often, too, emit a bad smell, due generally to the decomposition of organic matter present in the air, by contact with the heated sides of the stove and chimneys, or occasionally from the diffusion of carbon monoxide and other gases through the heated sides of the stove. These objections can in great measure be obviated by the use of wrought iron, and having the joints more securely riveted than is commonly the case; or the stoves may be lined with fire-brick and covered with tiles, as is seen in the better class of houses on the Continent.

Gas, of later years, has come into very general use both for

warming and cooking; it is admirably adapted for the latter, being not only cleanly but economical. For heating purposes, it has not made the progress which its many advantages deserve, probably owing to defective forms of stove used. Speaking generally, there may be said to be four common forms of gas-stove in general use: there are (1) reflector stoves, (2) condensing stoves, (3) asbestos or hollow-ball refractory fuel stoves.

The *Reflector stove* has usually a naked gas-flame, backed by a glass or metal reflector. It is bright and cheerful-looking, but gives out little heat, and unless provided with a flue—which more often than not is not provided—very considerably adds to the vitiation of the air.

Condensing stoves are those so constructed that the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and then caught in a tray beneath. This condensed vapour naturally carries down with it some if not all the sulphur products, but fails to remove any of the carbon dioxide which, notwithstanding all statements to the contrary, really escapes into the room. For this reason, this stove always requires a flue; unfortunately, its heating powers are small.

Stoves fitted with *asbestos fibre* or refractory hollow-ball fuel, and lighted by Bunsen or Argand burners, are relatively popular, owing to the fact that the fuel is rendered incandescent, with a close resemblance to the glow of an ordinary coal fire. These stoves yield radiant heat only as a rule, though a few are made with attached hot-air chambers, to give off heated currents of air. These are in the main good stoves, but somewhat extravagant as gas consumers, and always needing a flue to carry off products of combustion, and which as well takes off much of the heat which they produce as so much waste.

A recent and great advance is the Clamond gas radiator, in which the intense heat from a Kern flame is translated into radiant heat by surrounding it with a perforated fire-clay tube. The whole radiator consists of a number of these tubes placed over Kern burners, each consuming two cubic feet of gas per hour. The Kern burner is a modified Bunsen. Experiments made with the Clamond radiator show that it gives a cheerful, healthy, radiant heat combined with economical consumption of gas, and little or no deterioration of the air. Possibly, as electricity comes into more general use, a more extended employment of electric radiators for heating purposes will be a feature of many houses. On sanitary grounds, electric radiators are much to be recommended, as they emit heat without adding to the atmosphere any of the ordinary products of combustion.

Hot Air, obtained by driving air over hot bricks or pipes, is occasionally introduced into rooms and public buildings for heating purposes, by means of mechanical arrangements such as fans, as used in artificial ventilation methods. This is very efficient as a way of combining warming with ventilation, but is very costly. A modified application of this method has been

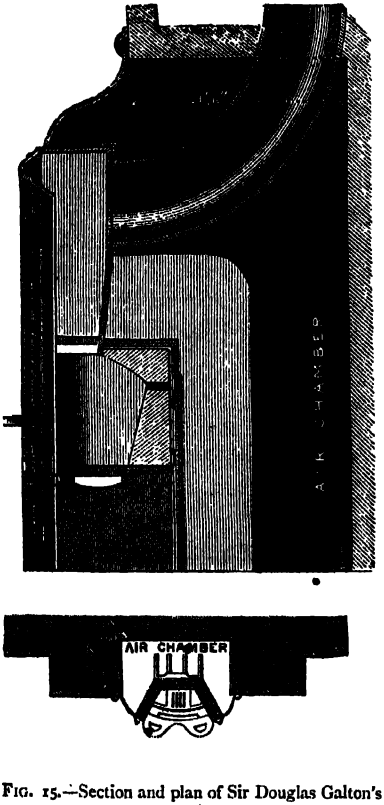


FIG. 15.—Section and plan of Sir Douglas Galton's grate.

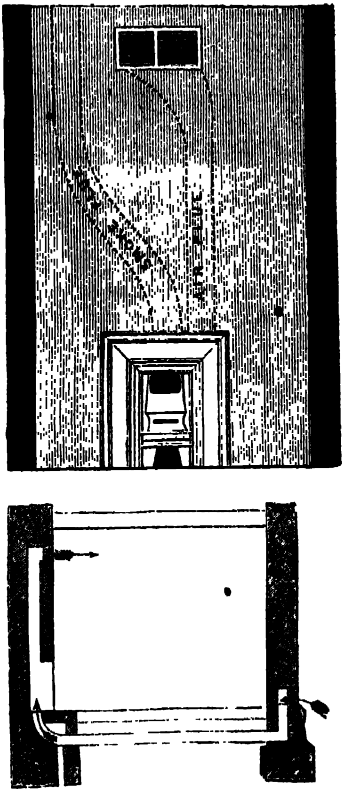


FIG. 16.—Elevation of Sir Douglas Galton's grate, and section of room, showing air-duct and flues.

designed by Sir Douglas Galton in the form of a stove, in which the fire which warms the room is also utilized to supply warm air. Figs. 15 and 16 show the existence of an air-chamber behind the grate, in which the air is warmed by the iron back, upon which several broad iron flanges are cast so as to obtain a large surface of metal to give off heat. The fresh air is obtained

by means of an inlet flue from the outside, and, after being warmed, is passed into the room near the ceiling by the opening shown in the illustration. These stoves, known as Galton's ventilating stoves, are in general use in the British army for warming and ventilating barrack-rooms and hospital wards.

The chief objection to the use of hot air as a general means of warming a room or dwelling lies in the fact that heated air is often unpleasantly dry, and when so employed should be moistened, or, if need be, purified by either filtration or washing.

Steam or **Hot Water** is closely allied to hot air for warming purposes. The ease with which all parts of a building can be heated by pipes containing steam or hot water is obvious, and, as applied to the needs of hotels, hospitals, churches, etc., is practically supplanting all other methods of warming. In the present day, steam is very little used for this purpose, since water, at either high or low pressure, is so much more convenient and cheaper. In a low-pressure water system the pipes are about 4 inches in diameter, and are always in a double row to allow of the water circulating. The boiler in connection with it is commonly placed in the basement of the building, and from its upper part runs a main pipe, ending in branches, which extend to the furthest end of the building; these then return underneath the others, unite into another single pipe, and then re-enter the boiler at its bottom. The circulation of the water is dependent upon the water, after being heated, being lighter than when cold, and as such tending to rise to a higher level; this having given up its heat to the various rooms, returns cooled by the lower pipe. The heat of the pipes is controlled by a valve which can be opened and closed at will. A feed-pipe from a supply cistern enters the return pipe near the boiler, while an escape for air is provided at the highest point of the system. In the high-pressure system, such as Perkins's, water is heated to about 300° F., in a portion of the pipes which pass through the kitchen fire. This system secures a greater heat, but requires very careful management, as any failure in the circulation would at once result in an explosion. Under the low-pressure system, 5 feet of a 4-inch pipe will warm 1000 cubic feet of air from 32° F. to 55°, and 12 feet will warm the same to 65°; but under the high-pressure, in which the heating power is something like two-thirds more, a proportionately less length of piping is required.

For calculating the necessary radiation for any given house or building, the construction of such building must be considered as to the kind of outside walls, their thickness and material. So, too, the height of rooms will make a difference, while the ventilation must be also taken into consideration, and provision made

to renew the air at least once an hour. The following general rules are given by Lawler:—

1. Allow 1 square foot of direct *steam* radiation for each 3 square feet of glass.

2. Allow 1 square foot of direct *steam* radiation for each 30 square feet of exposed or outer wall.

3. Allow 1 square foot of direct *steam* radiation for each 100 feet of space or contents of room.

It requires more radiating surface for hot-water heating than is necessary with steam, for the reason that the average temperature carried in a hot-water system is much lower than in a steam system. In round numbers, it requires about 25 per cent. more radiation surface for hot water than for steam. Lawler gives the following general rules:—

1. Allow 1 square foot of direct *hot-water* radiation to 2 square feet of glass.

2. Allow 1 square foot of direct *hot-water* radiation to 25 square feet of exposed wall.

3. Allow 1 square foot of direct *hot-water* radiation for each 75 cubic feet of air-space.

The Practical Examination of Air and Ventilation.

It has already been pointed out that the simplest test as to whether the ventilation of a room or a house is sufficient or not, is that of entering it from the external air, and noting the difference between the indoor air and the outside atmosphere in point of freshness. This test, however, only gives approximate results, and, in cases where more exactness is required, a more detailed examination is necessary. This, in every case, may be conveniently made to include the following points:—

1. The actual amount of cubic space, the relative size and position of inlets and outlets, and the amount of fresh air supplied.

2. The chemical examination of the contained air for impurities.

3. The nature of the suspended impurities.

4. Facts concerning the temperature and moistness of the air.

The determination of the actual amount of cubic space is merely a simple matter of measuring and calculation, combined with the making of certain deductions for bedding, furniture, etc., and irregularities in the shape of the space to be examined or additions for the cubic contents of open recesses. For each bedstead and bedding a general allowance of 10 cubic feet is made, and for the body of each adult 3 cubic feet. If the room be

rectangular or regular in shape, its cubical contents will be obtained by multiplying together the three dimensions of height, length, and breadth; if the space be irregular in shape, with either rectilinear or curved lines, it is usually most convenient to divide it up into simple parts, such as either triangles or circles, as the case may be, and calculate the cubical contents by one or more of the following rules. It is generally more convenient, too, to make the measurements in feet and decimals of a foot, than in feet and inches. If square inches are used, they may be turned into square feet by multiplying by 0·007.

Area of a circle = square of the circumference × 0·0796 or square of the diameter × 0·7854.

Circumference of a circle = diameter × 3·1416.

Diameter of a circle = circumference × 0·3183.

Area of an ellipse = the product of the long and short diameters × 0·7854.

Area of a square = the square of one of the sides.

Area of a rectangle = the product of two adjacent sides.

Area of a triangle = height × $\frac{1}{2}$ base, or base × $\frac{1}{2}$ height.

Area of any figure bounded by straight lines = divide it into triangles and take the sum of their areas.

Area of the segment of a circle = ($\frac{2}{3}$ × chord × height) $+ \dfrac{\text{cube of height}}{2 \times \text{chord}}$.

Cubic capacity of a solid triangle = area of a triangle × height.

Cubic capacity of a cylinder = area of base × height.

Cubic capacity of a cone or pyramid = area of base × $\frac{1}{3}$ height.

Cubic capacity of a dome = area of base × $\frac{2}{3}$ height.

Cubic capacity of a sphere = cube of diameter × 0·5236.

Thus, supposing it were required to determine the cubic capacity of a room 10 feet in height, and whose floor and ceiling shape were as drawn in the Fig., ABGCD. By dividing it into triangles and the segment of a circle, and then measuring the length of the various dotted lines, its total cubical capacity would readily be obtained. Assuming AB to be 6 feet, BC to be 8 feet, CD to be 6 feet, BD to be 10 feet, BE to be 7 feet, ED to be

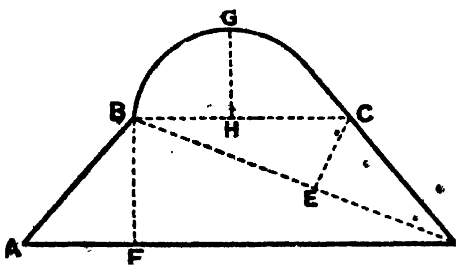


FIG. 17.

3 feet, FD to be 9 feet, FA to be 4 feet, EC to be 4 feet, GH to be 3 feet, and BF to be 5 feet, we get the cubical capacity of each of the figures to be as follows:—

		Cubic feet.
ABF . . .	$4 \times \frac{5}{2} \times 10$	$= 100$
FBD . . .	$9 \times \frac{5}{2} \times 10$	$= 225$
BEC . . .	$7 \times \frac{4}{2} \times 10$	$= 140$
CED . . .	$3 \times \frac{4}{2} \times 10$	$= 60$
BGC . . .	$(\frac{3}{1} \times 8 \times 3) + \frac{27}{2 \times 8} \times 10$	$= 177$
This gives a total cubic capacity of . .		702

Having determined the total number of cubic feet, with all deductions and additions, and dividing this sum by the number of persons living in the room, the result is the cubic space per head; whilst the total area of the floor-space divided by the number of persons, gives the floor-space per head; this we know should be as near as possible $\frac{1}{12}$ of the cubic space. When this has been done, the next thing is to count the various openings in the room, and note the direction of movement of the air through them. As a general rule, one-half of the openings will be inlets and the other half outlets, but this is not always so; the actual condition of affairs will be best learnt by observing the directions given to smoke disengaged by smouldering brown paper, velvet, feathers, or even light balloons. The direction of the air-currents being known, their rate of movement must be determined either by an anemometer, if such be available, or by calculation of the theoretical velocity as obtained by Montgolfier's formula, allowance being made, of course, for friction. If the ventilation is meant to be effectual when doors and windows are shut, these should be closed during this examination.

It may be accepted as a good rule that the amount of air issuing up a chimney or other large outlet is a far more reliable index of the fresh air being supplied than the amount actually ascertained to be entering through inlets; in fact, the fresh air supply can be rarely fairly estimated in any other way, as the air, even in the best of built houses, enters through many chinks and crevices, or even through porous walls themselves, in such a way as to be beyond all absolute or accurate calculations.

Having, then, made these various preliminary inquiries, it may be necessary to chemically examine the respired air itself, in which case samples of the air must be taken at such times as will yield fair evidence as to the efficiency or not of ventilation. Thus, in the case of a bedroom, the sample yielded during daytime, with no one in the room, would be no value as an index of the state of

the air during the night, when its usual occupants were sleeping in it. Therefore all samples should be collected at an hour when the greatest accumulation of impurities is likely to occur. For sleeping rooms this will usually be best secured at any hour between midnight and 5 a.m.

For the collection of an air sample, the simplest method is to obtain a glass jar or vessel, provided if possible with an indiarubber cap or stopper, and capable of holding from half to one gallon, and then accurately measure its capacity. If this be filled with clean water, and, after emptying it in the room or air-space it is desired to examine, the jar be then carefully closed with either an indiarubber cap or stopper, the contents of the vessel will be so much of the air required to be examined. Since the amount of hurtful organic impurity in air increases or diminishes with the quantity of carbon dioxide given off by persons inhabiting any particular air-space, the estimation of this gas constitutes the chief chemical examination required for ventilating purposes. For its determination the following method, known as Pettenkofer's, is at once the most simple and the most useful.

Estimation of Carbon Dioxide in Air.—Having filled a Winchester quart bottle, or other suitable vessel of known capacity, with clean water, and emptied it in that part of the air-space it is desired to examine, taking care to let it drain well, pour into it 60 c.c. of freshly prepared lime-water, and close it with an indiarubber cap or stopper. Shake the air and the lime-water in the bottle well up together, and allow to stand for half an hour or so. During this time the carbon dioxide in the air within the bottle will be absorbed by the lime-water, and its causticity or alkalinity proportionately lessened. The loss of strength, therefore, of the lime-water will be an index of the amount of carbon dioxide present; but the strength of the lime-water must be previously determined, and this is usually done by means of a solution of oxalic acid, consisting of 2·25 grms. of oxalic acid dissolved in 1 litre or 1000 c.c. of distilled water, and of which 1 c.c. consequently exactly neutralizes 1 mgm. of lime, forming oxalate of lime. The exact point of neutralization can be determined by turmeric paper. If the strength of 30 c.c. of the fresh lime-water be tested, it will generally be found to be between 30 and 40 mgms. of lime. If, now, the strength of 30 c.c. of the lime-water which has been kept in the bottle of air for awhile be examined, it will be found to be much less, and the difference or loss of alkalinity represents the number of milligrammes of lime which have combined with the carbon dioxide of the air in the bottle.

The milligrammes, however, of lime need to be converted into terms of carbon dioxide, by calculation of the proportion

between their molecular weights, which is as 56 is to 44, and then the CO_2 converted from milligrammes or measures of weight into cubic centimetres or measures of volume, which have a ratio one to the other as 1·9707 is to 1.

Suppose, in a jar of a capacity of 4385 c.c., it is found that 30 c.c. of lime-water, after standing some while, lose alkalinity, represented by 6 c.c. of the oxalic acid solution, equivalent to 6 mgms. of lime (CaO), then for the 60 c.c. of lime-water put in the jar the alkalinity lost is equal to 12 mgms. of lime. Since lime is to carbon dioxide as 56 is to 44, therefore 12 mgms. of lime equal 9·4 mgms. of CO_2. But milligrammes of CO_2 are to cubic centimetres of CO_2 as 1·9707 is to 1, therefore 9·4 mgms. CO_2 equal 4·76 c.c. of CO_2. Now, the original capacity of the jar was 4385 c.c., and, deducting 60 c.c. for the lime-water put in, we get the jar to hold 4325 c.c. net of air in which we have found 4·76 c.c. of CO_2, which is in amount equal to 1·1 c.c. of carbon dioxide in 1000 c.c. of air.

If the air of the room be above or below 32° F., a correction must be made by adding or deducting, as the case may be, 2 per 1000, or 0·002 for each volume. The reason of this correction being required is because the ratio between weight and volume of CO_2 as given above is only true for the precise temperature of 32° F., and consequently the volume of air must be corrected for just so much as the heat of the air varies from that temperature. Suppose the temperature of the room, when the sample of air was collected, had been 55° F., that is, 23° above the standard of 32°, therefore $23 \times 2 = 46$ per 1000 of CO_2 must be added to what has been shown above, simply because there was that amount less of air in the jar at that particular temperature than there would have been had the temperature at the time of collection been at 32°; the result of this correction means that instead of 1·1 parts of CO_2 per 1000 of air being present, the true amount is 1·15 per 1000, or as $1000 : 1046 :: 1·1 : x = 1·15$.

A further correction for barometric pressure may be made, if the height of the place is much above sea-level, or if the barometer read below the standard level of 29·92 inches; the correction being 0·26 per cent. for each difference of $\frac{1}{10}$ of a degree in pressure. As a rule, however, this correction is very rarely required.

Estimation of Organic Impurities in Air.—Besides the estimation of carbon dioxide, the chemical examination of air, strictly speaking, includes the determination of the organic matter and the ammonia in it. To obtain a merely approximate idea of the organic impurities, the air may be washed or drawn through a very dilute solution of permanganate of potash, of a known strength, and the result expressed as so many cubic feet of the

air which it takes to decolourize 1 mgm. of the permanganate. The estimation of the ammonia in air is a still more delicate process, and is performed by washing the air with ammonia free water, and then estimating in the water the ammonia yielded by the air; the actual process is described in the following chapter on water. As tests for the determination of various degrees of respiratory impurity, both the estimation of the organic matter capable of being oxidized by permanganate and of the ammonia present, are quite subsidiary to that for determining the carbon dioxide, and but rarely employed.

Examination of the Suspended Matters in Air.—This will, of course, be essentially microscopic. The suspended matters contained in the air of any particular space or locality may be conveniently collected by drawing the air through distilled water, then, after allowing the suspended matters to subside, to examine them under the microscope; or the air may be drawn or sucked into an exhausted receiver, through a fine aperture, so as to strike upon a piece of glass moistened with glycerine, which, of course, arrests the suspended matters. This is practically the plan of Pouchet's æroscope. Another plan is to aspirate the air through a filter of very finely powdered sugar; this is then dissolved by water, leaving the suspended matter of the air, which had been, as it were, caught, available for examination. As an alternative to these plans, one may take a bent glass tube and sterilize it by making it red hot in a flame; after this, immerse it in a freezing mixture of ice and salt, and slowly aspirate air through it. The moisture of the air drawn through is condensed inside the tube, sinks to the lowest point of the bend, having entangled all suspended matters with it. These can be readily transferred to a slide, and examined under the microscope.

These methods are not sufficiently exact to secure bacteria, moulds, or any of the smaller micro-organisms. Various instruments have been proposed to enumerate and examine the more minute micro-organisms in the air; but, on the whole, the work in this direction has been imperfectly successful. Perhaps the best method is that with Hesse's instrument. He aspirates air slowly through a wide horizontal glass tube, the interior of which, after careful sterilization by heat and washing with alcohol, is smeared or coated with nutrient gelatine. The air enters through a hole at one end, and at such a slow speed as to allow all the suspended particles to fall upon the gelatine before reaching the other end. On being placed in favourable conditions, the various micro-organisms grow upon the gelatine, and can be subsequently examined as to their precise nature. As a rule, the bacteria are much less plentiful than the moulds and fungi, but in air which

has been rendered impure by either respiration or by other effluvia, the exact reverse is found to be the case.

In carrying out all inquiries as to ventilation, the various facts connected with the temperature and moisture of the air need to be ascertained. These observations will be best made by means of thermometers to measure the heat, and by hygrometers to estimate the amount of moisture present. Details regarding the nature and use of these instruments will be more conveniently given in a subsequent chapter upon meteorology and meteorological instruments.

In a room, well ventilated and warmed, the temperature should not fall below 60° F., the moisture or humidity ought to range between 72 and 77 per cent., while the carbon dioxide, as previously stated, should not exceed 1·0 part per 1000 volumes of air.

CHAPTER II.

WATER.

Water is found widely diffused in Nature, and enters into the structure of plants and animals as well as nearly every tissue of our bodies. As a solid, we meet with it in the form of snow and ice; as a liquid, in the sea, in streams, rivers, and lakes; while, as vapour, it forms one of the constituents of the atmosphere, and of the breath which we exhale from our lungs. It is by means of the water we take in with our food that the solid portions of it are changed and dissolved, and its nutrient principles enabled to enter into the blood, to enrich it, and thereby build up the body tissues. The supply of water is, therefore, a fundamental necessity, and health depends greatly upon a supply of it, sufficient in quantity and pure in quality.

Water is a chemical compound, consisting of two atoms of hydrogen with one of oxygen, and is formed whenever hydrogen gas or a combustible substance containing hydrogen is burnt in oxygen or atmospheric air. In its purest state it is free from taste and smell, and, between 32° and 212° F., under ordinary atmospheric pressure, is a transparent, tasteless, inodorous, and almost colourless liquid.

In its liquid state, water is about 770 times more dense than ordinary air, this density being actually at its maximum at 39°·2 F. or 4° C. The density of water is always taken as the standard of comparison in reference to the densities of other

liquids or solids. In this country the density of water at a temperature of 60° F., and at the standard pressure of the atmosphere, 29·92 inches of mercury (760 mm.), is usually taken as unity, but on the Continent the temperature of its maximum density is more usually adopted, namely, 39°·2 F. or 4° C.; if cooled below or heated above this temperature, it expands. Some idea of the weights of certain volumes of water, in terms of both our own system of weights and measures and that of the metric system as used on the Continent, will be gathered from the following table:—

Grains.	Cubic centimetres at 4° cent. as grammes.	Cubic inches at 60° F.	Pounds.	Gallons at 60° F.	Cubic feet at 60° F.
1					
15·432	1	0·061		0·0002201	0·0000353
252·456	16·386	1			
7000	454·345	27·727	1	0·1	0·016046
70000	4543·458	277·276	10	1	0·16046
436495	28315	1728	62·355	6·2355	1

Water possesses a certain amount of elasticity and compressibility. Thus, by increasing the pressure by the weight of 200 atmospheres to which water is exposed, its volume is said to be reduced $\frac{1}{12}$ inch. This compressibility of water increases as the temperature rises. Water has a high capacity for heat, but yet it is a very bad conductor of heat. When water is heated from below, the heated portions of it expand, and thus, becoming specifically lighter, tend to rise to the surface, while the colder and denser parts of it sink until they, in their turn, being heated, the whole mass acquires a uniform temperature.

At a temperature of 32° F. or 0° C. water becomes solid or freezes, and at the same time suddenly expands; on freezing 1 volume becomes 1·09082, an increase of nearly one-eleventh of its volume, a fact which explains the reason why, during frosts, frozen pipes burst or split, and why damp soils or rocks containing moisture tend to crack during frost. This solid water or ice has a less density than liquid water, its specific gravity being 0·91674, consequently ice always floats on the surface of the water, and, since the density of water is greatest at 39°·2 F., or a few degrees above that of freezing, it consequently follows that such portions of it which are cooled below that point or freeze remain at the surface, while the water just below remains a few degrees warmer.

As already explained in the chapter on "Air," water evaporates from its surface at all temperatures, and its vapour thus formed has a density and tension determined by the temperature. Under the ordinary pressure of the atmosphere, which has also been explained as being equal to 29·92 inches of mercury, water boils at a temperature of 212° F. or 100° C., and is converted into 1698 times its own volume of vapour, or roughly 1 cubic inch of water yields 1 cubic foot of steam. If the pressure be reduced to nearly that of a vacuum, the boiling-point of water is nearly that of 32° F. or 0° C.; but if the pressure be increased, then the temperature of the boiling-point is raised, as shown in the following table:—

Pressure, in atmospheres.	Temperature of boiling-point.	Pressure, in atmospheres.	Temperature of boiling-point.
	F.		F.
1	212°	8	341·7°
2	250·5°	10	358·8°
3	275·7°	20	418·4°
4	293·7°	25	439·3°
5	307·6°	30	457·1°
6	320·3°	35	472·6°
7	331·7°	40	510·6°

The boiling-point of water under the ordinary pressure of the air is slightly influenced by the nature of the vessel in which it is heated, and by the smoothness or roughness of its surface. Thus in smooth vessels, like those of glass or porcelain, water boils at a higher temperature than in those with a rough surface, like iron. Water has a remarkable power of dissolving substances, and there are but few substances which water cannot to some extent dissolve. Generally the solubility of solid or liquid substances is increased in proportion as the temperature is raised, but there are exceptions to this rule: in the case of gases, the amount which water can dissolve is largely dependent upon pressure; and under ordinary pressure it is generally larger in proportion as the temperature is lower. The watery solution of solid substances and of certain liquids and gases have a higher density than ordinary water, but, as a rule, the density of watery solutions of liquids and gases is less than that of water. The freezing-point of water solutions is lower than that of water, thus sea water, which is largely a solution of various salts of magnesium, sodium, and potassium, freezes less readily than fresh water. The boiling-point of water is raised when it contains solid substances in solution, and this to an extent largely proportionate to the amount of substances in solution.

The latent heat of water is 80 thermal units; the change of one pound of ice to one pound of water at the same temperature requires as much heat as will raise one pound of water through 80° F. This quantity of heat represents the latent heat of the fusion of ice or the latent heat of water.

Quantity of Water required.—The amount of water used varies very much in different communities, being dependent on the conditions of the place and population. In London, the Water Board delivers 28¼ gallons per head daily, for domestic purposes. Edinburgh uses 40 gallons, Dublin 35 gallons, Glasgow 50 gallons, Berlin 15½ gallons, Vienna 22 gallons, Paris 44 gallons.

Water is required for drinking and cooking purposes, for personal ablution, for the washing of clothes, utensils, and houses, for the cleansing of closets, and for flushing drains and sewers; these amounts are generally included under domestic supplies. In towns, streets have to be watered, horses and cattle supplied, provision made for extinguishing fires—public fountains and trade purposes generally provided for. Roughly about fifteen gallons per head a day are required for domestic purposes, and about five gallons more for flushing drains and sewers—making twenty gallons; the average for trade and public supplies in towns may be taken at an additional ten gallons. The following table gives in detail the approximate quantities usually allowed:—

	Gallons daily for one person
Cooking	0·75
For drinking	0·33
Baths	5·0
Share of house washing	3·0
Share of laundry washing	3·0
If a general bath add	4·0
Water-closets	6·0
Unavoidable waste	2·92
Total	25·0
For town purposes, etc.	5·0
Add for manufacturing towns	5·0
	35·0

An adult man will drink from 50 to 60 ounces daily, exclusive of the amount of water contained in his so-called solid food; but the quantity varies, depending upon the season of the year and the occupation of the individual. Women and children drink less water than men. With a constant supply in towns there is no doubt considerable waste, and by due economy a smaller quantity would suffice.

The amount required for animals varies, and depends, as in the case of men, on the food, season, and exertion. During hot weather horses need more water than with a cold season. The following quantities approximate as closely as possible to the amount required :—

	Gallons.
Large oxen	6
Small oxen	5
Horses	8
Mules and ponies	6
Sheep or pigs	1

In the army, twenty gallons are allowed daily for each horse. This amount includes that necessary for the washing of both horses and carriages, and seems ample.

In hospitals a very much larger supply is required, and generally the amount used is double the ordinary supply, the average being from 60 to 70 gallons per head daily. The London Hospital uses 62 gallons; St. Thomas's Hospital, 99 gallons; the Royal Victoria Hospital, at Netley, 70 gallons; the Cambridge Hospital, at Aldershot, 90 gallons; the Herbert Hospital, Woolwich, 89 gallons.

Rain Water.—All natural water is derived from the rainfall. From the surface of the sea and from the land, water rises, under the influence of the sun's rays, in the form of invisible vapour; it forms clouds by being separated from the air, and descends under changes of temperature in the form of rain, dew, mist, snow, sleet, and hail. Part of this water is again evaporated, part flows off in the form of streams and rivers, while part sinks in through cracks and fissures into the earth until it reaches an impermeable stratum, where it forms the ground water, and flows beneath the surface of the ground at varying levels towards the sea or nearest water-channel, or finds its way to the surface in the form of springs.

Rain water varies with the purity of the atmosphere through which it has passed, and if collected in clean vessels as it falls in the open country, is usually very pure and wholesome. Near the sea it may contain chlorides and sulphates, derived from the sea itself. It is soft, owing to the absence of the salts of lime and magnesia.

As rain descends through the air it takes up from the atmosphere about 25 c.c. of gases per litre, of which about 34 per cent. is oxygen, 64 per cent. nitrogen, and 2 per cent. carbon dioxide. In addition, ammonia is usually present, and any suspended matters which may be floating in the air, so that before it reaches any collecting surface it may have added to it as much as

two grains of solid matter in a gallon of water. The average solid impurity in rain water throughout England is 2·4 grains in one gallon of water. In inland districts, especially where large manufacturing works are carried on, these impurities may be increased by the additions of sulphurous and sulphuric acids, and generally with the products of coal combustion, which may be either suspended or dissolved in the air.

Rain water is very frequently contaminated by impurities taken up from the surfaces on which it falls; such impurities generally consist of bird-droppings, decaying leaves, soot, and such matters as collect on the roofs of buildings; if the water is acid it will dissolve lead from the gutters, or zinc, should that metal be present or the water be collected from galvanized iron buildings. In order to prevent the suspended matters passing into the storage tank, a rain-water separator is sometimes used. The separator is made of zinc upon an iron frame, the centre part, or cantor, being placed upon a pivot; it directs into the lower waste-pipe the first part of the rainfall, which washes away the impurities from the roof. After a certain quantity (about one gallon on each 100 square feet) has fallen, the separator cants over, and turns the clean water into the storage tank. The separator acts automatically (Fig. 18).

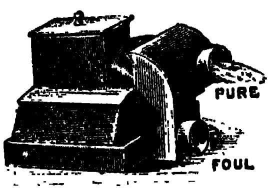


FIG. 18.—Rain-water separator.

The rainfall varies in different districts. On the east coast of England it is about 20 inches annually, on the south coast 30 inches, and on the west coast about 70 inches. The mean rainfall for England and Wales may be said to be 34·25 inches annually; for Scotland it is 43 inches, and for Ireland 39 inches.

The quantity of water which can be utilized from the rainfall may be calculated if the amount of the rainfall and the area of the receiving surface is known. It is necessary to know not only the average quantity which falls in any district, but also the amount which falls in the wettest and driest year. Hawksley states that the average of twenty years, *less* one-third, gives very accurately the amount of rain in the driest year; and the same average, *plus* one-third, gives very nearly the amount in the wettest year. The average of the three driest years in twenty is a safe basis on which to calculate the supply.

It is estimated that one-third of the rainfall flows off the surface and finds its way directly into streams and rivers, one-third is taken up by vegetation or evaporated, and the remaining third sinks into the earth; but this can hardly be even an approximation to

the truth. The available rainfall for storage will depend rather on the nature of the soil, the inclination of the ground, the temperature and moisture of the air, and the presence or absence of vegetation. On an average six-tenths of the rainfall is available for storage.

A simple method for calculating the amount of water given by rain is to multiply the area of the receiving surface in square feet by half the rainfall in inches, the result is expressed in gallons; the error here is only about 4 per cent. One inch of rain delivers 101 tons by weight, or 22,617 gallons on each square acre. If the inches of rainfall be multiplied by 14½, the result equals the millions of gallons per square mile.

Springs and Rivers.—Rain, flowing over and through the land, supplies springs and rivers. The amount which flows off the surface in streams or which penetrates into the ground depends on the configuration of the surface, the nature of the soil, the season and temperature, and, to a lesser extent, on the movement of the air. In summer, owing to an increase of temperature, evaporation is rapid, and less water penetrates the surface or runs off in the direction of the natural watercourses than in winter; the ground is drier, and more readily absorbs moisture. Evaporation is 50 per cent. less on a flat district than on an undulating rocky country. In a clay district hardly any water will sink into the ground, while a very large amount infiltrates into a loose sand or gravel soil. In the magnesium limestone districts about 20 per cent. of the rainfall penetrates into the ground; in the new red sandstone, 25 per cent.; in the chalk, 42 per cent.; and in loose sands, 96 per cent.

Penetrating into the ground, rainfall absorbs carbon dioxide from the air as it passes through the interstices of the soil, which is nearly 250 times richer in this gas than the air above it; aided by this and by the temperature of the soil and pressure,

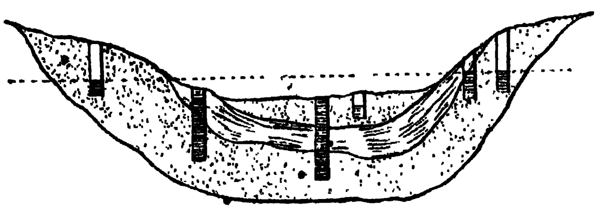


FIG. 19.—Diagram showing the tapping of the ground water above and below an impermeable stratum.

it dissolves from the soil lime, and everything else that it meets with which can be taken up in the time from the strata through which it passes.

It also takes up organic matter from the soil, more especially when it falls on cultivated lands and inhabited areas, and the organic acids derived from this organic matter, aided by increased temperature and pressure, increase the solvent properties of the water by exercising a powerful chemical action on the substances present in the soil and underlying rocks.

Springs are the outcrop or overflow of the ground water. The rain which falls on a permeable stratum percolates downward until

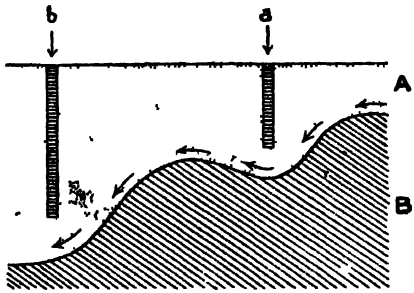


FIG. 20.—Diagram showing flow of the ground water, A being a permeable and B an impermeable stratum

it is arrested by a bed of clay or other impermeable stratum, and there becomes stored underground until it rises to a point or level at which it can spontaneously appear at the surface.

Mineral springs yield water containing dissolved mineral matters in solution which render them unfit for ordinary drinking purposes, though they possess medical properties of great value.

River water is derived partly from springs, but its chief source is from that part of the rainfall which flows off from the surface of the ground.

If the supply is taken from the head waters or source of the river before impurities can gain access to the water, it is generally pure, and the water has all the characters of an upland surface water. Unfortunately, most rivers are subject to pollution in their course, either from drainage from cultivated lands or from the sewage of villages on their banks being permitted to pass into them.

The composition of the water will therefore vary according to the part of the river whence it is taken. As a rule the dissolved mineral constituents in river water are in less quantity than in spring water, but the organic matters are present in greater quantity. Besides dissolved matters, river water usually contains suspended matter, both organic and inorganic, living and dead.

The organic matter which thus gains access to the water is to some extent oxidized and rendered innocuous in those rivers in which the current is rapid and where the water in its flow is broken up by rocks and boulders and exposed to the action of the air; the presence also of aquatic and bacterial life assist in its purification; but even then this is no safeguard when sewage is permitted to foul the water. Rivers or streams are sometimes dammed up so as to form an impounding reservoir, as in the case of the Vyrnwy, supplying Liverpool, and the Vartry at Dublin. These waters afford good supplies provided the gathering grounds are efficiently protected.

Wells are either shallow wells or deep wells. A well of 50 feet in depth or less is generally regarded as a shallow well; one of 100 feet or more, as a deep well. Shallow wells draw their supply from the subsoil water, while deep wells tap the water-bearing stratum beneath the impervious stratum: the latter are sometimes of great depth, and are called Artesian wells, having been first sunk in the province of Artois, in France. The water from these wells is generally pure, but it is not unusual to find in it a large amount of chloride of sodium and a good deal of free ammonia, it is generally poor in oxygen, not well aerated, but is moderately palatable. Deep-well waters are much harder than other classes of water, for they dissolve out much lime, magnesia, and the alkaline salts in their long course underneath the surface of the ground.

Wells furnish water supplies to most rural districts, and their depth generally depends upon the nature of the soil and on the

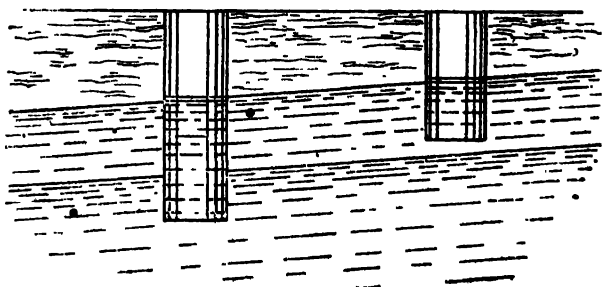


FIG. 21.—Diagram showing how a sudden rise in ground water may lead to communication between cesspool and well, previously disconnected.

height of the underlying ground water. Shallow wells may yield good water provided there is no risk of pollution from surface washings or from their proximity to drains and cesspools, but in every case it is wise to go deep enough to place an impervious stratum between the water supply and the surface of the ground,

and thus to effectually shut off surface impurities from entering and fouling the water in the well. If this cannot be done, the well should be sunk as deep as possible into the water-bearing stratum, and protected by steining with brick and cement, this being carried sufficiently high above ground to prevent surface washings from entering the well.

The distance drained by wells is undetermined: it has been given as a circle, the radius of which is the depth of the well, but there are good grounds for believing that much larger areas are affected, and that the flow of water has been influenced at a distance many times the radius; the pressure of tidal rivers has been known to influence the wells at Budapest at a distance of 2700 feet. Wells are largely influenced by the nature of the soil, by the movement and direction of the ground water, and by the amount of water drawn from them. A porous soil with no impervious superficial stratum will admit of impurities reaching the well from the surface which a clay soil would shut off. The movement and course of the ground water being in the direction of the nearest watercourse or the sea, to protect the water supply from any soakage from leaky cesspools or other sources of pollution, the well should be placed above them, to windward, as it were, of all such possible sources of contamination.

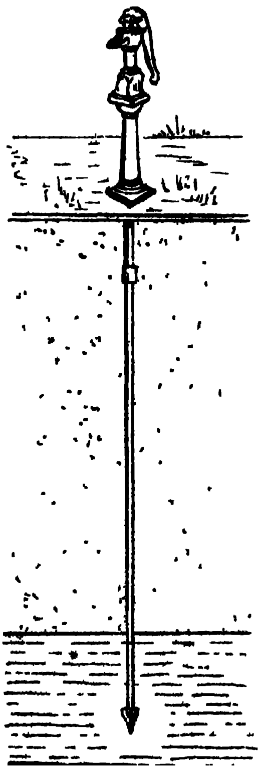


FIG. 22.—Tube well.

A well which yields a moderate quantity of good water may, if the demand on it be increased, draw in water from the surrounding parts to meet the supply, and thus tap sources of impurity which a moderate demand left untouched. A sudden rise in the ground water may also lead to direct communication between a cesspool and a well, by the water tapping the former in its flow.

Tube wells, commonly known as Norton's Abyssinian tube wells, are used when a temporary supply is required: they are superior to dug wells, which, from imperfect steining, or total absence of it, are liable to become foul from surface pollution. They are constructed by driving

tubes into the soil, one length being screwed on to another, the first tube being perforated at the bottom for about two feet, its lower end being furnished with a steel point (Fig. 22).

When the subsoil water is reached, a pump is attached to the tube; the water after pumping a short time is clear; the tube forms a cavity which corresponds to the ordinary well at the end of the pipe, owing to the removal of the soil by pumping. Koch recommends that iron tubes be placed in dug wells, and the surrounding space filled in with clean gravel and sand, the water to be raised by a pump fixed at the surface.

Collection and Storage.—When water is required for towns it is generally collected in reservoirs and distributed by gravitation. The amount required depends on the quantity used and the ease of replenishing. When these conditions are known, it is easy to calculate the space required; thus, if the number of gallons used daily be divided by 6·23 we get cubic feet, and these multiplied by the number of days for which the storage must last, gives the necessary size of the reservoir in cubic feet. Experience shows that the storage supply in this country should be not less than 150 days' consumption. Hawksley's formula for storage is $D = \frac{1000}{\sqrt{f}}$; where D is the number of days' supply to be stored and f is the mean annual rainfall in inches. Thus, with a rainfall of 36 inches annually, we get $D = \frac{1000}{\sqrt{36}} = \frac{1000}{6} = 166$ days' supply.

Reservoirs are placed on as high ground as possible, to give a sufficient head or pressure of water, so that every part of the district may be supplied by gravitation; from thence the water is distributed by cast-iron pipes. Service reservoirs should be covered and ventilated, and the water from the supply reservoir carefully filtered through filter-beds of sand before it is permitted to enter the service reservoir for distribution. In form they should be deep rather than extended, as this lessens evaporation and secures coolness. In case of ground supplies obtained from wells or springs, the water is generally free from organic growths, and in storing it in service reservoirs it is only necessary that no opportunity should be given for the growth of organisms. If the supply is taken from surface water there is usually some organic growth present, and the water has to be freed from this by filtration, so as to convert it into a ground water, and then in both cases to protect it from the action of light; it is now recognized that the growth of fungi in water, stored in reservoirs, can be prevented by the exclusion of light. All reservoirs require periodical cleaning.

If the storage reservoir is so large that it cannot be covered in, a second or service reservoir, capable of holding a few days' supply, should be provided, into which, after filtration, the water from the storage reservoir might be conveyed as required.

Distribution.—Water collected as thus described may be distributed on the *constant* system, in which the supply pipes are always kept full of water, or on the *intermittent* system, in which the water is only turned on at intervals for a short time during the day. The constant supply is the one usually aimed at, as no cisterns are required for storage, and the drinking water is taken direct from the main. When the supply is intermittent it is necessary to have cisterns in which to store a sufficient supply of water during the intervals that the water in the mains is turned off; the mains, being empty of water, are liable to be fouled by impurities in the soil, such as gas from leaky pipes lying in their vicinity, or actual sewage from a neighbouring leaky sewer or drain-pipe; the foul air, aided by the suction action of the pipe when the water is turned off, enters through the joints, which are not infrequently caulked with tow and gaskin, and are not impervious. Under proper supervision the waste of water is less on the constant system than on the intermittent system of supply.

Water is usually distributed by iron pipes, called *mains*, laid some distance underground, the thickness of the pipe being dependent on the pressure to which it is subjected by the head of water. The lengths of pipes are put together by a spigot joint packed with lead. The practice of caulking with tow and gaskin and then running the joint with molten lead seldom secures a proper joint; the tow and hemp rot, and contaminate the water as well as causing waste from leakage. Cast-iron pipes, unless protected, rapidly corrode, especially if the water is soft. It is usual, therefore, to coat these pipes with a protective material before laying them down. Angus Smith's process is the one very generally adopted. A varnish distilled from coal tar until the naphtha is entirely removed is deodorized and a small quantity of linseed oil added; this mixture is carefully heated in a tank to about 400° F., when the pipes are immersed in it, and allowed to remain until they attain a temperature of 400° F. Some engineers prefer Barff's method, which consists in raising the temperature of the metal to about 1200° F.—a white heat—in a suitable chamber, into which is passed super-heated steam; the metal is exposed to this action for several hours, and becomes coated with a protective oxide; this plan has not hitherto proved very successful. Iron pipes last longer if kept constantly full of water, and are not so liable to corrode as those which are alternately full of air and water.

The disadvantage of the constant-supply system is the greater waste from leaky pipes, due to settling of the ground after laying, to fracture from pressure owing to heavy traffic, and the expense of the renewal of the fittings, which must be of the best description; but in practice it has been found that with proper fittings there is no great loss. A plan has been recently introduced by Deacon by which any large waste occurring in any district may be at once detected. He has invented a water-waste meter, or detector, which registers the flow of water both by day and by night. These are fitted to each district main, and as only a very limited quantity is used at night, any waste can be at once detected, since what passes through the metre must run to waste. The place where the leakage occurs can be localized by the vibrations produced in the nearest house-pipes, and which are audible on applying the ear to the stand-pipe. By this method leakage can be at once found out, and an enormous saving of water effected.

Service-pipes communicating with houses are made of lead, wrought iron, or galvanized iron; lead pipes should only be used when it has been proved that the water has no action on that metal. Soft waters are especially liable to act on lead, an oxide of lead being formed which is dissolved again; for such waters, composition pipe, made of an amalgam of lead and tin, has been used, and is said to answer. Iron pipes coated with vitreous glaze are best, and have proved successful when all others have failed, but on account of the difficulty in fixing them, and their cost, they have not come into general use. Galvanized-iron pipes are now very generally used; they are not liable to rust, and stand the pressure of the water well. Block-tin pipes are excellent, but very expensive: water does not act on them, and they last for a long time; their cost, however, is almost prohibitive against their coming into general use. Composite pipes, consisting of block tin enclosed in a lead pipe, are not liable to be acted on by water, but if the surface of the tin is fissured, either in fitting the pipe or by frost, galvanic action takes place, and the lead is rapidly dissolved; they are, however, said to answer where they have been used. The best service-pipes for general use are wrought-iron pipes protected by Barff's method or coated with Angus Smith's preservative: if pipes coated inside with a vitreous glaze are not considered too expensive, this latter is a perfect material, as it is not affected by acids in the water, and does not yield any unpleasant taste to water.

The action of water on iron pipes appears to diminish after their use for a short time. Barff's method has also been applied to service-pipes, and appears successful; it is said, however,

that the coating of protective oxide does not last, but soon wears off.

Cisterns are usually made of slate, stone, iron, galvanized iron, or lead; the latter should never be used when the water supply is taken for drinking purposes. Slate, set in good cement, is an excellent material, but is liable to leak at the joints; in no case should red lead be used to repair these cisterns. Common mortar should not be used, as it gives up lime to water. Stoneware makes a good cistern, but its weight is against its use. Iron cisterns rust and discolour the water; they may, however, be protected by being lined with cement (Crease's patent). Galvanized-iron cisterns are those most generally used; they have been known to give up zinc to water, but this is so exceptional that it should not prohibit their use. They should, however, be thoroughly coated with a good asphaltum paint. Cisterns should be so placed as to be easy of access and readily cleaned. If the water is exposed to frosts, the sides should be made to slope: this will prevent their fracture by the expansive force of the freezing water. The overflow or waste-pipe should not communicate with any drain, but open free to the air above a grating sufficiently high to prevent foul air rising through it and contaminating the water. For the same reason the supply pipe of any water-closet should not pass direct from the cistern, but a smaller cistern (water-waste preventor) should intervene.

To permit of cisterns being periodically cleaned, it is better to have two smaller cisterns than one large one, so that there may be no inconvenience in emptying the one or the other at any time. Cisterns should always be covered to protect them from dust, soot, and other contaminations, as dead mice, birds, etc.; they should also be ventilated and protected as far as possible from both heat and light. Tanks to hold rain water require even more constant care than cisterns, as the water carries impurities with it from the roofs of buildings, from which it is generally collected.

With an intermittent supply, the cisterns in the smaller class of houses are not large enough to fulfil the requirements of the occupants, and stand-pipes are generally erected to supplement the supply; the need of these is avoided where the constant service has been introduced, and the evils attendant upon the storage of water are thereby prevented. A great waste has often followed on the change from the intermittent to the constant service, mainly due to the fittings not being able to stand the greater strain placed on them; constant supervision is required to see that this is not a cause of waste. Screw-down taps should always be provided, and not a common stopcock, as there is less pressure on the pipe when the water is turned off slowly. The water drawn direct from the main is cooler, and, as a rule, better aerated

than when stored in cisterns. Some water companies introduced a ferrule or throttle of very small diameter, so as to allow the water to pass extremely slowly from the taps, but the inconvenience and inutility of the practice has caused its discontinuance. A screwcock to turn off the water just as it enters the house is also necessary, so as to shut off the supply if needed; this is very essential during frost, and, if supplemented by a tap at the lowest part of the pipe so as to enable the water to be drawn off, there will be little danger of pipes bursting from this cause.

Pipes, if made of lead, should be sufficiently strong to stand the strain of high-pressure supplies; they are usually 9 lb. per yard for 1-inch pipes, and 21 lb. per lineal yard for 2-inch pipes. In order to limit waste, many companies propose to deliver in special cases water by meter, but this would have the disadvantage, if applied to communities, of restricting the use of water, which is not advisable. The advantages of the constant service in the case of fire is obvious.

Action of Water on Lead.—The apparently inscrutable behaviour of certain waters, especially soft moorland waters, in regard to plumbo-solvent ability, may be said to be now understood. For this explanation we are indebted to the work of Houston on behalf of the Local Government Board. Preliminary inquiry had shown that the plumbo-solvency of any water was associated always with corresponding variations in the amount of acid in the water. Extended inspection and investigation of all the chief moorland gathering grounds of Yorkshire and Lancashire has shown that the cause of the plumbo-solvency is due to the acid in the waters, which acid is formed by contact of the water with the moist peat on the catch-ground, and that the formation of the acid is due to the presence of acid-producing bacteria in the peat itself. An important point is brought out in this Report to the effect that there is a difference in kind of action exercised by water on lead. In one case the action (plumbo-solvency) is brought about by acidity of the water; in the other the action (erosion) is an inherent property of water containing dissolved air. The erosive action, as distinguished from the true solvent action of acid waters, shows itself by the formation of a relatively insoluble compound or powder (oxhydrate of lead), which may tend to fall away from the surface of the metal, and so permit of progressive action. Fortunately, however, erosion takes place only to any large extent when the lead is bright, and, moreover, most natural waters contain ingredients which prohibit the action. Neutral distilled water erodes lead vigorously. Interesting as this phase of the subject is, it is quite secondary in practical importance to the question of plumbo-solvent ability, which is

due to acid in the water derived from acid peat, and formed by acid-producing bacteria in the peat itself.

As to remedial measures, the experiments seem to indicate that in practice it might be cheaper to resort to a preliminary lime or combined lime and sand filtration treatment than by employing carbonate of sodium, by this means correcting acidity, plumbo-solvent ability, and gross erosive power, and then supplementing this procedure finally with a further addition of sodium carbonate in minimal quantities, so as, by endowing it with a reserve of protective substances, to place the water in a condition in which the possession of erosive ability would be impossible. There seems to be this difference between erosion and plumbo-solvency, that any mere neutralizing treatment, even if carried out imperfectly, always renders an acid water, as regards plumbo-solvency, less dangerous than before; whereas, as regards erosive ability, insufficient treatment may produce no appreciable inhibition, and may in certain cases render such partially treated water more prone than before to attack lead. In cases where doubt exists as to the plumbo-solvent ability of a water, it is suggested that to be deemed "safe" it should give a neutral reaction with lacmoid solution of an ascertained activity, and also fail to dissolve an appreciable quantity of lead when filtered through a glass tube containing lead shot. Similarly, all doubtful waters should be tested as regards erosive ability by placing them in contact with bright lead. A water containing as much as $\frac{1}{10}$ of a grain in the gallon is unfit for drinking purposes, and even $\frac{1}{20}$ of a grain may be unsafe, as this amount has been known to affect some persons. Filtration removes lead from water, if the filters act properly.

Quality of Water Supplies.—Rain water, if properly collected and stored, affords an excellent supply in country districts. In towns it takes up such impurities from the air and from the various collecting surfaces on which it is gathered, that it cannot be looked upon as satisfactory. The uncertainty of the supply and the length of a dry season necessitates large storage capacity, which is not desirable. Rain water should be filtered to remove suspended matters before being stored, and the tanks protected from light and heat. The hygienic value of rivers, springs, and wells as sources of supply depends on many details. Spring water may be both pure and impure; it is generally, however, free from organic impurity, while its mineral constituents are large. River water, on the contrary, is more liable to vegetable and animal contamination than springs are, while its mineral constituents are less. Shallow-well water should always be viewed with suspicion, by reason of the danger from surface pollution during heavy rainfalls.

Hard and Soft Waters.—Water is frequently described as *hard* and *soft.* Hardness is due to the presence in the water of the salts of lime and magnesia. If it is in the form of carbonates, and if its amount is not excessive, it renders water palatable, and does not interfere with its wholesomeness; but if, on the other hand, it is caused by the fixed lime and magnesia salts, it is objectionable. Hard waters are also wasteful, as in washing much soap is expended before a permanent lather is obtained. Vegetables boiled in such water tend to become hard, and are difficult to digest. The difficulty of infusing tea with such water is well known.

The following tables show the characteristics of water from different sources (*Rivers Pollution Commissioners' Report*):—

1. In respect of wholesomeness, palatability, and general fitness for drinking and cookery—

Wholesome	1. Spring water	very palatable.
	2 Deep-well water	
	3. Upland surface	moderately palatable.
Suspicious	4. Stored rain water	
	5. Surface water from cultivated lands	
Dangerous	6. River water, to which sewage gains access	palatable.
	7. Shallow-well water	

2. Classified according to softness with regard to washing, etc.—

1. Rain water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river waters.
5. Spring water.
6. Deep-well water.
7. Shallow-well water.

3. As regards the influence of geological formation in rendering the water sparkling, colourless, palatable, and wholesome, the following water-bearing strata are most efficient:—

1. Chalk.
2. Oolite.
3. Greensand.
4. Hastings Sand.
5. New Red and Conglomerate Sandstone.

The general characters of a pure and wholesome water are as follows. It should be clear, sparkling, showing that it is well aerated, free from colour and taste, and not too hard, so as to

interfere with the cooking of vegetables, etc. There should be no sediment, and if any, it should consist only of a little mineral matter. Where there is any marked deviation from this standard, the cause of it should be carefully inquired into.

Impurities in Water.—The geological formation of a district influences the composition of the water which passes through it; while affording a valuable guide, it by no means tells with absolute certainty what the constituents of the water may be. The following soils generally yield a supply of pure water:—granite, metamorphic and clay slate soils, hard oolite and chalk. Water from these soils is usually very pure, containing a little lime and magnesia, carbonate and sulphate, but a very small amount of organic matter. Waters from the sands, sandstones, and gravels vary greatly in composition, and are uncertain sources of supply; the greensand waters are usually good, and in clean gravels, if not situated near towns, the water is often free from impurities. Sometimes the sands contain large quantities of soluble salts, which are dissolved by the water; frequently, also, the organic matter is high. The limestone and magnesium limestone waters are usually free from organic impurity, but may contain the fixed hard salts—calcium sulphate and magnesium sulphate—in excess; they are not as desirable a source as the chalk waters.

The chalk waters are clear, sparkling, well aerated, being highly charged with carbon dioxide; there is usually a very small amount of organic matter present, and, although hard, they can be very effectually softened; they are wholesome waters, as a class, and are pleasant to drink. Fissures sometimes exist in the chalk, by which impure water may be admitted to wells without having undergone any process of filtration.

Surface and subsoil water are a common source of supply in country districts; these waters should always be regarded with suspicion, unless taken from places which are far removed from possible pollution. In gravelly and sandy soils, the power of oxidation is so great that organic impurities become rapidly oxidized and rendered harmless. Such waters are always dangerous, although possibly they may not be actually injurious. Marsh waters are soft and well adapted for washing purposes, but the vegetable organic matter is high, and there is usually much suspended matter present. In tropical countries, such waters are unfit for drinking purposes, as they may produce malarial fever in a severe form.

Artesian-well water varies; it frequently contains an excess of sodium chloride and carbonate, and there is usually present free ammonia in considerable quantities; it is generally flat and insipid, and for this reason is not very palatable.

Wells situated near the sea-coast usually contain a large amount of saline mineral matter. In cases where this is excessive, surface wells and rainfall afford the only available sources of supply.

Effects of drinking Impure Water.—Although it is a generally recognized fact that any large and sudden outbreak of epidemic disease in a community, especially if it is localized, is usually due to the pollution of the water supply, yet there are many instances on record where its use has been the cause of ill-health, without producing such marked effects. The diseases which are associated with the use of impure water are cholera, enteric fever and dysentery, dyspepsia and diarrhœa; malarial fever in tropical countries, goitre, parasitic diseases, and metallic poisoning. The virulence of an epidemic disease has some definite relation to the purity of the supply, for, once seeded with the specific poison, a polluted water appears to act more virulently than one that is pure. From our knowledge of the presence of infective micro-organisms, it would appear doubtful whether they survive in good water for any lengthened period. Laboratory experiments show that from 14 to 40 days has been the maximum period of their vitality, and probably under less favourable conditions a much shorter period would complete their life.

Waters containing an excess of the fixed hard salts of lime and magnesia frequently cause diarrhœa and dyspeptic symptoms, especially among those who are unaccustomed to use them. Carbonate of lime does not appear to have any injurious effect, nor, on the contrary, is it essential, as it was formerly believed to be; if it is, it is best to have it in some other way than in drinking water. Diarrhœa has been caused by the suspended matters in water, which affect the intestinal tract by mechanical irritation. Waters to which sewage gains access may produce diarrhœa in those who are not used to them, though long habitude in the use of such waters appears to induce a condition in which the system tolerates them. Goitre is a disease said to be caused by drinking water derived from limestone and dolomitic rocks; that goitre is prevalent in places where the water is very hard is undoubted; but it is also said to exist where the drinking water is soft and contains very little of the sulphates of lime and magnesia. This disease has also been attributed to the presence of iron pyrites in the water. The question is one that has not been definitely settled; probably water is really only one factor in the causation of this disease.

That dysentery has been caused by impure water there is ample evidence to prove; in nearly every instance, the water was polluted with fœcal, and probably with dysenteric discharges, and where the supply was discontinued, the disease disappeared; it

may also be said that water contaminated with organic impurity acts as a predisposing cause by exercising an irritative action on the bowels, as well as being directly the vehicle by which the specific poison is introduced into the system.

Enteric fever is more often spread by impure water than by any other means. The disease is usually regarded as being associated with a specific poison, although some observers recognize that it may also have a *de novo* origin. It is, however, abundantly proved that specifically infected water does produce this disease, and that the subsequent dilution of the poison by an enormous quantity of water is no safeguard, once sewage infected with the germ gains access to the supply. Barry's report on the Tees water supply clearly showed that the incidence of the fever fell on those districts which drew their water supply from the River Tees, while those who drew their water supply from other districts escaped. In this epidemic, the attacks were spread over all the several districts—ten in number—supplied with this water, several districts being attacked simultaneously; while, apart from the water supply, there was no difference of any importance between those drinking the Tees water and the other districts which were free from the epidemic. Chemical examination fails to show whether a water is contaminated with this specific poison or not, and the difficulty attending a bacteriological examination has not enabled this test to be made generally applicable; yet the presence of other constituents in sewage, which gain access to the water at the same time as this specific micro-organism, are sufficient in most cases to permit of a conclusion being drawn from a chemical examination. Cholera is a disease due to a specific micro-organism contained in the evacuations of those suffering from the disease, and is propagated chiefly by means of drinking water infected with the specific poison. The evidence of its spread by specifically infected water has been well demonstrated during the epidemic at Hamburg, where those taking their drinking water from the Elbe, which was imperfectly filtered, and to which sewage had access, suffered severely from cholera, while those living on the outskirts of the city, and under similar conditions in every respect, except the source from which their drinking water was obtained, were not affected by the epidemic. In India, the testimony of all sanitary officers affirms the intimate connection which exists between cholera epidemics and impure and polluted drinking water.

As with enteric fever, so with cholera, the poison gains access to the water by the discharges of those suffering from the disease being allowed to enter defective sewers, leaky cesspools, privies, etc., the contents of which infect the subsoil water or are carried

direct into rivers or streams, from which drinking water is taken.

Malarial fever has been caused by drinking stagnant water and water from marshes in tropical countries. In such waters, there is always a large amount of vegetable organic impurity present, as well as the larvæ of mosquitoes: certain species of these insects have been shown to be intimately associated with the dissemination of the *plasmodium* of malaria to man, and it is probable that the drinking of water containing ova and larvæ of malarially tainted mosquitoes may be one of the means whereby man contracts the infection.

Ova of parasitic intestinal worms are frequently found in water, and may gain access to the stomach by drinking. The more common forms are as follows:—*Tænia solium*, *Ascaris lumbricoides* (round worm), *Tænia mediocanellata*, *Bothriocephalus latus*, *Distomum hepaticum* (liver fluke of sheep), *Oxyuris vermicularis* (thread-worms). Also in tropical countries, the *Filaria sanguinis hominis* and *Filaria medinensis*.

Metallic poisoning may result from the absorption by the water of the metal used in the making of the service-pipes, cisterns, etc., by means of which the water is supplied or stored. The water may also be contaminated at its source by passing through a soil in which a metal is present, as in some mining districts, or a river may be polluted with metallic refuse from trade manufactures. Copper, zinc, lead, and arsenic are the most probable poisonous metals which may gain access to water in this way.

Purification of Water.—This subject may be considered in relation to (*a*) purification of water on a large scale as applicable to public water companies, before distribution of the supply, and (*b*) to domestic filtration as usually practised by the consumer in his own house. Water derived from the chalk undergoes a process of purification when the salts of lime are removed from the water before distribution for the purpose of rendering the water soft. Several methods have been used, but the basis of all of them is the addition of a measured quantity of milk of lime, calculated on the degrees of hardness of the water. Carbonates of lime and magnesia are soluble in water containing free carbon dioxide. When a solution of fresh lime is added to such a water in proportion to the degree of hardness present, the lime combines with the excess of carbon dioxide to form carbonate of lime, which is precipitated with almost the whole of the carbonate of lime originally held in solution by the water, and falls as a sediment, carrying down with it the organic impurities held in suspension; this action of adding lime-water to remove the

mineral matters (the salts of lime and magnesia) from a water may be expressed as follows:—

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O$$

It is necessary to know the exact degrees of hardness in the water, and to use only sufficient milk of lime as will combine with the carbon dioxide holding the chalk in solution, otherwise lime passes out into the distributing pipes. If an excess has been added, a few drops of a solution of nitrate of silver added to a small quantity of the water will produce a dark yellow colour, but only a white precipitate, if chlorides alone are present. The amount of lime added averages about 1 ounce per 100 gallons for each degree of temporary hardness. This treatment usually leaves only the permanent hardness *plus* some 2 grains per gallon of calcium carbonate in solution. In the Porter-Clark process, the suspended matters are removed by allowing the water to pass through a series of linen cloths under pressure. This has the advantage of rapidity, and removes the whole of the suspended matters effectually.

The permanent hardness of water is not touched by this process; this hardness is due to the soluble salts of lime or magnesia held in solution by the solvent properties of the water itself.

For the reduction of permanent hardness, the addition of lime, sodium, or sodium carbonate are needed: thus—

$$CaSO_4 + CaCO_3CO_2 + 2NaOH = 2CaCO_3 + Na_2SO_4 + H_2O$$

In waters where great permanent hardness is due to lime salts, then sodium carbonate must be used instead of caustic soda: thus—

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

In both cases, the addition of lime is needed for removal of the temporary hardness. Practically, each degree of hardness, as $CaCO_3$, is equal to 0·8 part NaOH, 0·56 part CaO, 0·74 part $Ca(OH)_2$, 1·06 part Na_2CO_3, and, for general use, the following rules may be laid down:—

(1) If the temporary hardness exceeds the permanent hardness, add NaOH equivalent to the permanent hardness, and lime equivalent to the excess of temporary over permanent hardness.

(2) If the permanent hardness due to lime exceeds the temporary hardness, add Na_2CO_3 in proportion to the permanent hardness, and then, if necessary, lime equal to the temporary hardness.

Water is nearly always submitted to some process of filtration before distribution; it is extremely difficult to obtain at its source a water which needs no purification, and in the great majority of

cases it is impossible to do so. It is the practice of most water companies to use sand and gravel as a filtering medium. Water is usually first passed into large reservoirs, where the suspended matters are allowed to subside by gravitation; these consist of mineral grit and clay in a state of fine subdivision and sand, all of which forms a deposit on the bottom of the reservoir. From thence it is led to filter-beds made of sand and coarse gravel, the former being from two to three feet in thickness, and lying on three or four feet of coarse sand and gravel, and from this the water is collected into a storage reservoir for distribution. Downward filtration is much more effectual than the upward or lateral passage of the water through the filter. To secure satisfactory bacterial purity the maximum rate of filtration should not exceed 4 inches, or 2·5 gallons per square foot of filter surface per hour. By these processes two means are employed to purify the water, viz. mechanical and chemical. The mechanical processes consist in allowing the heavier particles to subside, and subsequently arresting the suspended matters on the surface of the filter-beds. Sand filtration has not much effect on the chemical constituents of the water, but oxidation of the organic matter does to a limited extent follow on passing water through sand filters. The chemical changes produced on water by filtration have up to a recent period been almost the sole test as regards the capability of the material to purify water; recent investigations show that all that is really necessary is that mechanical filtration shall be perfect. Sand, although its effect on the organic constituents in water, as gauged by chemical analysis, is limited, is very effective in holding back micro-organisms, which, if they are not the actual cause, are intimately associated with those diseases spread by the agency of water, such as enteric fever, cholera, dysentery, etc. The chemical action which takes place is probably due to the presence of a nitrifying ferment in the sand as well as to air in the interstices of the sand itself; this action is not, however, regarded as being of much importance. The mechanical action which frees the water from micro-organisms is largely assisted by the deposit of mud on the surface of the filters, and it is now recognized that in sand we possess a most powerful medium for removing germs from water. Two conditions are, however, necessary to obtain the best results; these are (1) that the sand should be of a certain thickness, not less than 30 c.m. (1 foot), and (2) that the water should not flow through it at a greater pace than 4 inches in one hour, or 60 gallons daily per square foot of surface. The action of this filter is partly mechanical, partly vital; the mechanical action is confined to the holding back of the grosser substances which have not subsided, but remain suspended in the water; the vital

action consists in the layer deposited on the surface of the sand which is charged with microbian life, and it is by these organisms, which are constantly increasing in number, and which penetrate the sand to a slight distance, that both the nitrification of organic matter and the arrest of other microbes is effected. From this it is evident that in order to preserve the power of these filters, the surface layer should not be removed so long as water passes through it. Roughly stated, it may be said that a filter becomes "dead" (*i.e.* nearly impervious to water), and consequently demands cleaning once every three or four weeks in summer, and about half as frequently in winter; but it is not possible to lay down hard and fast general rules applicable to all filters. In some experiments recently undertaken in America, to test the power of sand filters in removing pathogenic bacteria, and especially that associated with typhoid fever from drinking water, it was found that 99½ per cent. of the applied bacteria were removed, and this goes to prove that these filters act efficiently when properly constructed as a safeguard against water-borne diseases. The rate of flow through the filter must not exceed 4 inches in one hour, and the rule should be that no water can be regarded as efficiently filtered that contains more than 100 micro-organisms in 1 c.c. of the filtered water. But cases will arise in which it is necessary to purify water, and when no regular system of filtration as above described exists or is possible, simpler and often ruder methods are all that can be devised.

Distillation is one of the best means, and that is very frequently practised on board ships. It is necessary that the water taken for this purpose should be as free as possible from contamination. Water distilled from sea water taken in harbours to which sewage was admitted has produced diarrhœa amongst those using it, possibly due to the large amount of free ammonia which came over with the distillate. The liability of such water also containing lead, taken from the pipes through which it passes, should not be overlooked.

Boiling is an excellent means for purifying water; the carbonate of lime is got rid of, and any hydrogen sulphide, and also some organic matter. It destroys most disease poisons, and it has been found that water which has been well boiled is safe to drink. Alum has been frequently used to purify water where there is much suspended matter; it acts best when calcium carbonate is present—calcium sulphate and a bulky hydrate of alumina precipitate being formed, which mechanically carries down the suspended matters with it; generally 5 or 6 grains of alum are sufficient to add to each gallon of water; it should be well stirred up in the water, and then set aside to allow the suspended matter to subside.

Latterly bisulphate of sodium has been recommended as a reagent for sterilizing waters of doubtful purity. Fifteen grains per pint of water is capable of sterilizing a much-polluted water in half an hour. The action of this salt depends upon its free sulphuric acid. Whether the consumption of this acid for any length of time in water may not lead to digestive trouble is not exactly known, but the weight of evidence goes to show that, except in cases of emergency, the use of chemicals for purifying water is undesirable.

Permanganate of potassium destroys odour and oxidizes much of the organic matter in solution and suspension. The permanganate should be added until a persistent pink tinge appears; it is advisable to supplement it by alum purification.

Animal charcoal is probably the material most in use for purposes of domestic filtration. Charcoal has the power of absorbing oxygen from the air, and probably condenses it within its pores. Its action is to oxidize organic matter, and to convert it into harmless products; that it does effectually, provided the charcoal is fresh, and if this was all that was required, or what resulted from its use, no better medium could be selected to purify water; but there are vital objections to its use as a filtering medium. It adds to water nitrogen and phosphates, both being the nutriment on which micro-organisms grow and develop. Its action on fresh, or, it may be said, vital organic matter is exceedingly feeble, while the charcoal itself readily absorbs impurities from the water or air, and is more of a danger than a safeguard against disease when it has been in use for a short time. Charcoal removes metallic salts, and in particular salts of lead, phosphate of lead being formed. The life of a charcoal filter is relatively short, depending on the quantity and quality of the water passed through it. Water cannot be stored with safety after filtration through animal charcoal, as micro-organisms develop rapidly in it. For these reasons it seems undesirable to use animal charcoal for the purposes of filtration; it is expensive, and not only in some cases inefficient, but dangerous. Vegetable charcoal has little power in furthering the oxidation of organic matter in water; like all filtering media, it acts mechanically in holding back micro-organisms, but only to a limited extent. Both are inferior for the purposes of filtration to sand, which has considerable power in preventing micro-organisms passing through it into the filtered water, while it yields no nutritive media that facilitates their growth; it retains this power for a considerable time.

Silicated carbon filters, in which a block of prepared carbon covered by powdered silicated carbon is used, should not be relied on to purify water. The suspended matters tend to deposit on it,

forming a slime on the surface, which contaminates the water it is supposed to purify. A filter which depends on a block of carbon alone is useless for the purposes of filtration.

Recent investigations go to show that the value of any filter does not so much depend on its action on the chemical constituents of a water supply as on its power of holding back micro-organisms, which are now generally admitted as being closely connected with the specific diseases.

Following on these lines, Pasteur devised a filter tube, or "bougie," made of fine porcelain, through which water is forced by pressure, the resulting filtrate being sterile. The pressure employed should not exceed two atmospheres. Its action is purely mechanical, and the chemical constituents of the water are in no way affected by its passage through the "bougie," or tube.

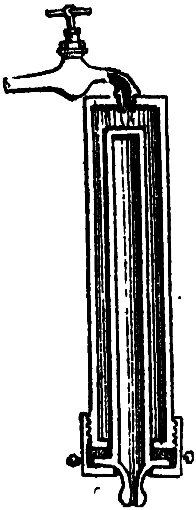


FIG. 23.—Pasteur-Chamberland filter.

Since these filters have been introduced into the French army, the number of attacks of enteric fever have diminished by 62 per cent., and as its use is extended it is expected that even more favourable results will accrue.

The Berkefield filter is somewhat similar to the Pasteur-Chamberland; it is made in the same form, but the material is infusorial clay, which has considerable power in mechanically arresting any matters present in water. This form of filter allows water to pass more rapidly through it, and does not require so much pressure; the material is softer, but whether it will bear cleansing as effectually as the porcelain is doubtful; it is, however, an excellent material for the purpose. Both these filters fulfil the conditions which modern bacteriological knowledge teaches as necessary to purify water; it also shows that the older class of filters were not only in many cases useless but were absolutely mischievous. The objection to the use of these modern filters is that a head of water, or pressure, is required, and that the rate of flow is very slow. The former difficulty is got over by a simple mechanical contrivance introduced by the inventors, by which pressure is given to force the water through the filter; the latter objection can be overcome by using several in place of one "bougie" only.

These filters act on water precisely as sand filters act on a large scale; they sterilize the water—that is, the pores are so small and the current of water so finely divided that micro-organisms

are unable to pass through. The filters have no action on the dissolved organic impurities in water, but it is of no less importance that water intended for drinking purposes should be free from these, as with such, no doubt, is associated the multiplication of micro-organisms, if not their virility and potency.

The rate of filtration through these filters depends mainly on the pressure of the water, which passes from without inwards. This is convenient, as the deposit, which tends to be and is gradually formed on the outer surface during use, can be easily washed or brushed off on removing the screw-tap. Although these "bougies," or candles, deliver sterile filtrates for a considerable time, often when left uncleaned, it must be remembered that they cannot do so indefinitely. Experiments made at Netley by Horrocks have shown that, when immersed in foul or polluted water, these filters, particularly those whose lacunar spaces are large, permit of the growth of pathogenic bacteria through their substance, and ultimately fail to yield sterile filtrates. This growth of bacteria through these filters may take place in as short a period as four days, hence the necessity, especially when foul water has been subjected to filtration, of sterilizing the filters every three days by careful immersion and scrubbing of their surfaces in boiling water. The only bougies which have failed to permit of bacterial growth through their interstices are the porcelain candles, or Pasteur-Chamberland filters. They, though certainly more reliable, deliver water much more slowly than others of a more open texture.

WATER ANALYSIS.

The results of a sanitary analysis of water must be considered in connection with many conditions, such as the locality and surroundings of the water, the depth or rate of flow of the river or lake, the season of the year, the conditions of the catchment area, etc.; if wells, their proximity to the sea, their depth, and, if possible, the strata through which they pass. Conditions such as these largely affect the interpretation of the results which a chemical analysis of a water gives. For example, the limit of free ammonia and chlorine allowed in a water taken from a deep well of 800 or 900 feet, would, if present in a surface well of 20 or 30 feet in depth, indicate contamination of a serious kind. The object of an analysis of water is to determine the amount of mineral and organic constituents, and to note for future examination the character of the suspended matters.

At the outset, a knowledge of the source of the water is necessary, whether a surface water or ground water. A surface

water nearly always contains animal and vegetable life, while water from the deeper strata is usually devoid of life until it is exposed to the action of light and air in reservoirs, under which conditions it assumes in this respect the characters of a surface water.

Collection of Samples. –In order to secure that the results of an examination of water should be of value, care must be exercised in the collection of the samples. Winchester quart bottles, holding half a gallon, are very suitable for the purpose; the bottle used should be carefully cleansed with a little hydrochloric or sulphuric acid, and then thoroughly washed out with pure distilled water or some of the water to be examined. When a sample is taken, the bottle should be filled quite full, and just sufficient poured off so that a little air-space is left under the stopper, care being taken that the inside of the neck of the bottle or the stem of the stopper be replaced untouched by the hand or wiped with a cloth. Corks should not be used except in great emergency, and then only if they are quite new and thoroughly rinsed in water before being used. No luting of wax plaster or similar material should be used.

In taking samples from streams, lakes, or reservoirs, the bottle should be submerged with its stopper in the water, and the stopper withdrawn 12 inches or more below the surface, so as to avoid collecting any of the water that has been in immediate contact with the air. If from a public water supply, the sample should be drawn from a hydrant in direct connection with the main, and not from a cistern or storage tank; if taken from a service pipe, the water should be allowed to run to waste for some minutes before it is collected. in order to remove that which has been standing in the pipe; the bottle should then be rinsed out at least three times, pouring out the water completely each time; the same practice should be adopted in the case of pumps.

Water should be examined as soon after collection as possible, and kept in a cool place not exposed to light.

It is important that with each sample the fullest information should be given of those conditions and surroundings which may influence the character of the water; especially must be noted the *source* of the water, whether from wells, rivers, cisterns, public supplies, etc. If a well, the depth and the depth of water in the well, whether steined or otherwise, the strata through which it is sunk, the position and distance as regards cesspools, privies, drains, etc., whether the land around is cultivated, whether a pump is attached, and if not, how the water is raised. If a cistern, how supplied; if by rain, the nature of the collecting surface and storage. If a public water supply, the source, and whether the water is supplied on the constant or intermittent system.

It should also be stated whether any disease is suspected to have been caused by the water, so that a bacteriological examination may be made if considered necessary. No point likely to afford information should be omitted.

Physical Examination of Water.—Water should be clear and free from turbidity. *Turbidity* is caused by the suspended matters in water, that which on standing for some hours settles to the bottom is its *sediment*. As a rule, surface waters are turbid, deep-well waters clear; the suspended particles may be finely divided clay, algæ or some other living form, animal or vegetable. The *colour* of water may be judged by looking through a stratum of water 12 inches deep; this can be done by using a tall glass placed on a sheet of white paper. Pure water is generally of a bluish or greyish colour. Yellow or brown waters are suspicious, as they frequently owe their colour to sewage, unless in peat districts or in places where iron is found, in which case the waters are not usually hurtful. The *taste* of water is a most uncertain guide; the taste depends almost altogether on the gases dissolved in the water, and not upon the soluble animal and mineral matters, unless these are in large excess. Any badly tasting water should be rejected. Taste also differs much in different persons. Common salt can only be tasted when 75 grains are added to 1 gallon of distilled water, and the other mineral constituents usually present must be large before they can be recognized. Iron is the only substance which can be tasted in small quantities.

The *odour* of water is best detected by heating it in a stoppered flask to 80° F. As a rule, the odour only lasts for a few moments, and should be judged by removing the stopper and smelling the water at once; it is sometimes a guide in polluted waters, and gives a clue to the origin of the pollution. Any offensive smell is sufficient to condemn a water.

The physical characters of a pure and wholesome water are freedom from any marked colour and from suspended matters, a brilliant lustre, devoid of any taste or smell. In a large majority of cases, water possessing these characters is fit for drinking purposes.

It is not intended in this manual to treat fully the subject of water analysis, which requires much elaborate apparatus and considerable chemical knowledge, but a few qualitative and quantitative tests are given, capable of indicating the general characters of a water.

Qualitative Examination of Water.—The *reaction* of pure water is usually neutral. If acid and the acidity disappears on boiling, it is due to carbon dioxide. If alkaline and the alkalinity disappears on boiling, to ammonia. If permanently alkaline, it is probably from sodium carbonate.

Litmus and turmeric papers are used to determine the reaction, which is usually red or brown.

Lime.—Add oxalate of ammonium; if lime is present, a white precipitate is formed: 6 grs. per gallon gives turbidity, 16 grs. a considerable precipitate.

Chlorine, with nitrate of silver and dilute nitric acid, gives a white precipitate: 1 gr. per gallon gives a haze, 4 grs. per gallon gives a marked turbidity, and 10 grs. a considerable precipitate.

Nitric Acid (nitrates). Add a solution of brucine (1 grm. in 1 litre of distilled water) and strong sulphuric acid. The sulphuric acid should be poured gently down the sides of the test tube to form a layer under equal parts of a mixed water and brucine solution. Half a grain of nitric acid per gallon gives a marked pink-and-yellow zone; or 2 c.c. of the water may be evaporated to dryness and a drop of strong sulphuric acid and a minute crystal of brucine dropped in—0·01 gr. per gallon can be easily detected.

Nitrous Acid (nitrites).—Nitrous acid decomposes iodide of potassium, and free iodine gives a blue colour with starch. Boil 20 grms. of starch intimately mixed with half a litre of distilled water; filter when cold, and add 1 grm. of potassium iodide. If a little of this solution is mixed with the water to be examined, and dilute sulphuric acid added, an immediate blue colour will appear, should nitrites be present; or Greiss's test may be employed. To 100 c.c. of the water add 1 c.c. of metaphenylenediamine solution (made by dissolving 5 grms. of metaphenylenediamine in 1 litre of distilled water, rendered acid with sulphuric acid, and decolourized, if necessary, with animal charcoal) and 1 c.c. of dilute sulphuric acid (1 in 3). A yellow colour, changing to red, will appear in the water in half an hour if there be only one part of nitrous acid in ten millions of water.

Ammonia is detected by Nessler's solution; if present in water, a yellow colour or yellow-brown precipitate is formed. If in small quantity the colour should be observed through a column of water 4 or 5 inches in depth, the glass being placed on a white ground.

Iron.—Ferrocyanide of potassium (yellow prussiate) gives a blue colour with ferric salts, and ferricyanide (red prussiate) with ferrous salts. The water should be rendered acid with dilute hydrochloric acid, free from iron. A comparative test should be made with distilled water.

Lead or Copper.—Place some water (100 c.c.) in a white dish, and stir with a rod dipped in ammonium sulphide; wait till colour is produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.

The following test is best applied to water concentrated to one-fiftieth part of its original volume:—

Magnesia.—Add oxalate of ammonium to precipitate the lime, then after filtration a few drops of phosphate of sodium, of chloride of ammonium, and of liquor ammoniæ. A crystalline precipitate of triple phosphate appears within twenty-four hours.

THE QUANTITATIVE ANALYSIS OF WATER.

The chief points which require determination in an ordinary quantitative analysis are the total solids, the chlorides, the hardness, and the organic matter as represented by what are called the free and albuminoid ammonia. If additional evidence as to the quality of the water is required, to these may be added the determination of the amount of oxygen absorbed, and the amount of nitrogen existing as nitrites and nitrates.

The main principle of a quantitative, or volumetric analysis, is the submission of the substance to be estimated to certain characteristic reactions, employing for such reactions solutions of known strength; and from the volume of solution necessary for the production of the reaction, determining the weight of the substance to be estimated by the application of the known laws of chemical equivalence.

To carry out any quantitative analysis, the first essential is the thorough comprehension of the simple relationship between liquids and solids. Owing to its uniformity and simplicity, in the following analytical methods, the metric system alone will be mentioned. Although tables of the various metric weights and measures are given in the Appendix, it may not be out of place here to emphasize the fact that a cube of distilled water at its greatest density, viz. 4° C., or 39° F., whose side measures 1 decimetre, has exactly the weight of 1 kilogramme, or 1000 grammes, and occupies the volume of 1 litre, or 1000 cubic centimetres. In other words, 1 cubic centimetre, as a measure of volume, equals or corresponds to 1 gramme as a measure of weight, and that

Grammes	of a	subst. diss. in	10	c.c.	of water	are	x	parts in	10
"	"	"	100	"	"	"	x	"	100
"	"	"	1000	"	(1 litre)	"	x	"	1,000
Decigrammes	"	"	"	"	(1 litre)	"	x	"	10,000
Centigrammes	"	"	"	"	(1 litre)	"	x	"	100,000
Milligrammes	"	"	"	"	(1 litre)	"	x	"	1,000,000
"	"	"	100	"	of water	"	x	"	100,000
"	"	"	10	"	"	"	x	"	10,000
"	"	"	1	"	"	"	x	"	1,000

It is most usual, in this country and on the Continent, to express the results of a quantitative analysis as parts per 100,000—that is, centigrammes per litre, or milligrammes per 100 cubic centimetres. This ratio will be adopted in the following analytical processes, while, for the sake of brevity, the term "cubic centimetre" has been written as c.c.

Occasionally, the expression grains per gallon is met with in English analysis. This is equivalent to parts per 70,000, as there are 70,000 grains in a gallon. The conversion of parts per 100,000 to grains per gallon is, of course, readily performed by multiplying by $\frac{7}{10}$, or by 0·7; and from grains per gallon to parts per 100,000, by multiplying by 10 and dividing by 7.

The Apparatus specially needed for making a Quantitative Analysis consists of

1. *A pair of balances and weights*, according to the metric system. In these sets of weights, the larger ones represent grammes, the next in size decigrammes, and the next centigrammes. Small foreceps are used for picking up and applying these weights to the pans of the balance. The milligrammes are added by shifting a little piece of bent wire along the cross-beam of the balance, which has on it ten markings, numbered from 1 to 10, on either side of the pivot.
2. *A platinum dish*, capable of holding 200 c.c. of water.
3. One or more shallow *porcelain evaporating dishes*, capable of holding 300 c.c.
4. A small *porcelain crucible*, with lid, for igniting residues.
5. *A pestle and mortar*, for powdering reagents previous to solution.
6. One or more *retorts*, or boiling flasks.
7. A Graham's, or Liebig's *condenser*.
8. Six *Nessler Glasses*, each capable of holding 100 c.c.
9. Glass *stirring-rods*.
10. Two glass-stoppered bottles, capable of holding 250 c.c.
11. Glass *funnels* for filtering.
12. A packet of Swedish *filter papers*.
13. A dozen *test tubes*, with stand, cleaner, and holder.
14. A *measuring flask*, to hold at least 1 litre and graduated in cubic centimetres.
15. Glass *burettes*, or graduated tubes, holding 20 c.c., and graduated in cubic centimetres and tenths of a cubic centimetre. One of these should be mounted on a wooden stand, and be provided with a stopper at the top, and fitted with a stop-cock at the bottom.
16. A glass *pipette*, graduated to deliver 10, 20, 50, or 100 c.c.
17. An iron tripod.

18. One or more triangles of iron wire, covered with pipeclay.
19. A pair of small crucible tongs.
20. A long thermometer, graduated in either Centigrade or Fahrenheit degrees.

Standard Solutions required in a quantitative analysis, are solutions of definite strength, made by dissolving a given weight of a reagent, in grammes, in a definite volume of distilled water in cubic centimetres. These solutions are usually made by dissolving either the hydrogen equivalent weight of a reagent in grammes, or some decimal part of such weight in 1000 c.c. (1 litre) of water. The following abbreviations are often used to express the strength of standard solutions:—

N = a normal solution	having	hydrogen equivalent weight in grammes per litre			
$\frac{N}{2}$ = a semi-normal	,,	$\frac{1}{2}$	,,	,,	,,
$\frac{N}{10}$ = a deci-normal	,,	$\frac{1}{10}$	,,	,,	,,
$\frac{N}{20}$ = a viginti-normal	,,	$\frac{1}{20}$	,,	,,	,,
$\frac{N}{100}$ = a centi-normal	,,	$\frac{1}{100}$	,,	,,	,,
$\frac{N}{1000}$ = a milli-normal	,,	$\frac{1}{1000}$	,,	,,	,,

In place of using the above normal or deci-normal solutions, it is often found convenient to use what may be called an empirical solution—that is, a solution of a reagent so made that a cubic centimetre has a value expressible as unity or some convenient figure or factor. Thus, an empirical standard solution of silver nitrate can be made to the strength that 1 c.c. is capable of precipitating 1 mgm. of chlorine. This is made by dissolving, not the hydrogen equivalent weight of silver nitrate, but that fractional part of it which is equal to one of chlorine. Taking $AgNO_3$ to be represented by 170, in terms of its hydrogen equivalent weight, and chlorine as 35·5, then 4·788 grms. of the silver nitrate dissolved in a litre of distilled water, would give a solution, a cubic centimetre of which would exactly equal 1 mgm. of chlorine.

Occasionally, in making standard solutions the equivalent hydrogen weight of a reagent cannot be taken, but its particular weight in a particular reaction in a given analysis has to be regarded. For instance, when using a solution of potassic permanganate, as an oxidizing agent, having the chemical formula $KMnO_4$, and the molecular weight of 158, and yielding five

volumes of oxygen in a particular reaction, its normal solution is made by dissolving one-fifth of its molecular weight, $\frac{158}{5}$, or 31·6 grms. in a litre of water. In other instances, when the hydrogen equivalent weight of a substance is not identical with the atomic or molecular weight, the amount taken is the equivalent weight. Thus, oxalic acid, $C_2H_2O_42H_2O$, with an atomic weight of 126, is a bivalent substance, and its equivalent weight is one-half of its atomic weight; consequently, a normal solution of oxalic acid would be made by dissolving 63 grms. of the crystallized acid in 1 litre of distilled water. Similarly phosphoric acid, which is a trivalent substance, would require, for the preparation of a normal solution of sodic phosphate, $Na_2HPO_412H_2O$, one-third of its molecular weight $\frac{358}{3}$, or 119·3 grms. being dissolved in 1 litre of distilled water.

Indicators.—In order to enable us to ascertain, by a change of colour or other marked effect, the exact point at which a given reaction is complete, certain substances, called indicators, are employed. The chief are as follows:—

(*a*) *Solution of litmus*, which turns red with acids and blue with alkalies.

(*b*) *Alcoholic solution of phenol-phthalein*, which is colourless with acids, but becomes red with alkalies.

(*c*) *Starch mucilage*, which turns blue in the presence of free iodine.

(*d*) *Solution of potassium chromate*, which gives a red with nitrate of silver, but not until all the chlorine or halogen present has entirely combined with the silver.

Estimation of Total Solids in a Water Sample.

The estimation of the total solids, by itself, is not of very great practical hygienic value, but affords a control over the other quantitative determinations. Take 250 c.c. of the water sample, place in an evaporating dish, and slowly evaporate down to 100 c.c., or less, carefully guarding against any of the solids remaining attached to the sides of the dish. Transfer the concentrated water and residue to either a small, clean, weighed crucible, or platinum dish. Evaporate to complete dryness, in air, water, or steam bath, at 105° C. So soon as the capsule is cold, reweigh: the difference in weight will be the amount of *total solids*. A simple form of steam bath can be made by taking a common two-gallon tin can, fitting a perforated cork into its mouth, and passing a funnel through the perforation. The crucible is placed in the funnel, water boiled in the tin can, and a little roll of paper placed between the funnel and the crucible to let the steam pass out.

Example.—Total solids, 250 c.c., dried as described—

	Grammes.
Weight of dish and residue	23·14
,, ,, alone	20·09
Difference being total solids in ¼ litre of water or 0·05 part in 250.	0·05

This multiplied by 400 or $0·05 \times 400 = 20$ parts of total solids in 100,000.

After the total solids have been determined, they should be slowly incinerated over a flame to dull redness, when any organic matter will give evidence of its presence by charring or by yielding dark fumes with the smell of burnt horn. Continue the incineration until nothing remains but a clear white mineral ash. If iron be present, the ash may be red; whilst manganese gives it a greenish tint. Having allowed the capsule to cool, weigh again; the excess weight now over that of the clean and empty dish represents the *fixed solids*, and the difference between them and the total solids gives the *volatile solids*.

Fixed Solids.—The above residue is incinerated as described.

	Grammes.
Weight of incinerated residue and dish	20·12
,, dish alone	20·09
Difference being fixed solids in ¼ litre of the water	0·03

This multiplied by 400 or $0·03 \times 400 = 12$ parts of fixed solids in 100,000.

Volatile Solids.

Total solids	20 parts	per	100,000
Fixed ,,	12	,,	,,
Difference being volatile solids	8	,,	,,

The total solids consist in most water samples of carbonates of calcium, sodium, magnesium, potassium, and iron; sulphates and chlorides of sodium, calcium, and magnesium; nitrites and nitrates of calcium, sodium, and potassium; with occasionally some phosphates of potassium and sodium.

The volatile solids consist generally of ammonia salts, nitrites, nitrates, some of the chlorides and carbonates, with water from sulphate of lime and destructible organic matter.

The amounts of total solids vary from 3 or 4 to 50 or 60 parts per 100,000. Of these not more than 3·0 per 100,000 should be volatile or lost on ignition.

Estimation of Chlorides in a Water Sample.

For this purpose two solutions are required.

(1) *A solution of Potassium Monochromate*, made by dissolving 50 grms. of the salt in a litre of distilled water. Nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle and the clear liquid decanted off.

(2) *A deci-normal standard solution of Silver Nitrate*, made by dissolving 17 grms. of $AgNO_3$ (molecular weight being 170) in a litre of distilled water. This will be equivalent to one-tenth of the atomic weight of chlorine (35·5), or 3·55 grms. of chlorine, and 1 c.c. of this solution will equal 3·55 mgms. of chlorine.

The process consists in taking 250 c.c. of the water sample, placing them in a white porcelain dish, and rendering them of a distinct yellow colour by means of two or more drops of the potassium chromate solution. From a burette, run in drop by drop some of the $\frac{N}{10}$ silver nitrate solution, stirring after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. As each cubic centimetre of the silver solution equals 3·55 mgms. of chlorine, the number of cubic centimetres used indicates the milligrammes of chlorine in 250 c.c. of the water—that is, parts per 250,000—and that divided by 2·5 or multiplied by 0·4 will give parts of chlorine for 100,000.

Example.—In 250 c.c. of water, rendered yellow with potassium chromate, 1·5 c.c. of silver solution gave a permanent red tint; then—

$$\frac{1{\cdot}5 \times 3{\cdot}55}{2{\cdot}5} = 2{\cdot}13 \text{ parts of chlorine per } 100{,}000$$

The purest water, as a rule, contains less than 1·5 parts of chlorine per 100,000. An increase may be due to sea water, to percolation through salt-bearing strata, to sewage or other impurities. Some deep wells often contain large quantities of chlorides; but generally an excessive presence of chlorine is a reason for suspicion unless a satisfactory explanation of its presence is obtainable.

Estimation of Hardness in a Water Sample.

The hardness of a water is conveniently determined by means of the soap test. Soap is an alkaline oleate resulting from the combination of an alkali with one or more of the fatty acids, *i.e.* oleic, stearic, or palmitic acids. When an alkaline oleate is mixed with pure water a lather is given almost immediately, but if

lime, magnesia, alumina, baryta, iron, or other similar substances are present in the water the soap forms oleates with these bases, and no lather is formed until these earthy bases are thrown down or used up. The hardness of a water depends upon the presence in it of more or less of these earthy bases, and the more they are present the greater will be the expenditure of soap to make a lather. Free carbon dioxide has a similar effect. The soap combines in equivalent proportions with these bases, so that if a solution of soap be graduated by a solution of known strength of any one of them, it will be of equivalent strength for corresponding solutions of any of the others. Owing to magnesia having a tendency to form double salts with the fatty acids, the results are not quite so accurate as for lime or baryta. A certain amount of the hardness of a water is removed by boiling, hence it is usual to speak of the hardness present before boiling as total hardness, that remaining after boiling as fixed or permanent hardness, and that which has been dissipated by the boiling as the temporary hardness.

The total hardness in most drinking waters is caused by salts of calcium and magnesium with some free carbon dioxide. Hence waters from the chalk, oolite, limestone, dolomite, and new red sandstone are apt to furnish the greatest degrees of hardness. Rain water, being free from these salts, is usually very soft. Many of the salts contributing to the total hardness are held in solution by carbon dioxide, and when the water is boiled this is dissipated, causing these salts to fall to the bottom or form incrustations on the sides of the containing vessel as insoluble salts. The chief of these are carbonates and sulphates of lime and magnesium, with salts of silica, alumina, and iron when these are present.

The permanent hardness, or what still remains in solution, consists mainly of some sulphates, chlorides, and nitrates of calcium and magnesium, with a little iron and alumina.

The Soap solution for the estimation of hardness is best made by thoroughly dissolving by stirring and warming some soft soap in a mixture of 4 parts methylated spirits to 6 of distilled water, and then filtering. This solution of soap should be standardized—that is, diluted or strengthened as the case may be, so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of nitrate of barium. Barium nitrate $Ba(NO_3)_2$ has a molecular weight ratio to calcium carbonate $CaCO_3$, of as 261 is to 100, and if 0·261 grm. of barium nitrate be dissolved in a litre of distilled water, that solution equals 0·1 grm. of calcium carbonate, and 50 c.c. of the same solution equals 5 mgms. of calcium carbonate. Now, if the soap solution be so made that 2·2 c.c. of it give a lather with 50 c.c. of the above barium nitrate

solution, after deducting 0·2 c.c. for the amount of soap solution necessary to give a lather with 50 c.c. of distilled water, we get 2 c.c. of the soap solution to equal 50 c.c. of a barium nitrate solution, which again is equivalent to 5 mgms. of calcium carbonate, hence each cubic centimetre of the soap solution equals 2·5 mgms. of calcium carbonate. Say, for instance, a small quantity of soap solution of unknown strength has been made, and on its being standardized with 50 c.c. of the barium nitrate solution, it is found that 1 c.c. gives a lather in place of 2·2 c.c. being so required. The soap solution measures 30 c.c. Then as $1 : 2·2 :: 30 : x = 66$; that is, the 30 c.c. must be diluted up to 66 c.c. to give a soap solution, of which 1 c.c. shall exactly equal 2·5 mgms. of calcium carbonate. Of course, if the soap solution be found too weak it must be proportionately fortified with more soap until 2·2 c.c. exactly give a lather with 50 c.c. of the 0·261 Barium nitrate solution.

To determine the Total Hardness, take 50 c.c. of the sample and place in a stoppered shaking-bottle. From a burette run in sufficient of the soap solution, until on being briskly shaken the contents of the bottle give only a faint dull sound with the formation of $\frac{1}{4}$ inch of fine uniform lather. This lather should show an unbroken surface after standing 5 minutes.

Suppose the addition of 2·4 c.c. of the soap solution have produced the necessary sound and lather. Deducting 0·2 c.c. as being necessary for the production of a lather in 50 c.c. of the purest water, we get 2·2 c.c. of the soap solution required by 50 c.c. of the water sample or 4·4 necessary for 100 c.c. Each of these cubic centimetres equals 2·5 mgms. of calcium carbonate; hence $4·4 \times 2·5 = 11$ mgms. of calcium carbonate in 100 c.c. of the water, representing a total hardness of 11 parts per 100,000—that is, 11° of hardness on the metrical scale. The original introducer of this soap test, Dr. Clark, used to express the hardness as so many grains per gallon, hence 11° on the metrical scale are the same as 7·7° on Clark's scale, or $11 \times 0·7 = 7·7$ grs. of calcium carbonate per gallon.

When the total hardness exceeds 20 parts per 100,000, an over-estimation may be made as the excess of calcium and magnesium interfere with the formation of the characteristic lather. In these cases it is better to dilute 25 c.c. of the sample with 25 c.c. of distilled water, proceed as explained, when the net amount of soap solution used will indicate the hardness in parts per 100,000.

To determine the Permanent Hardness, place 100 c.c. of the sample in a flask and boil for half an hour. On allowing to cool, all the calcium and magnesium carbonate, with most of

the iron, if any be present, will form a precipitate at the bottom of the flask, but some of the magnesium carbonate will have become redissolved. This precipitate will represent the temporary hardness for the most part, while the permanent hardness will still exist in the supernatant liquid. Carefully decant this clear liquid into a measuring-glass, taking care not to shake up the precipitate. Measure it, and make up to the original bulk of 100 c.c. with distilled water. Estimate the hardness, as explained above, in 50 c.c. of it. The result will be the permanent hardness, and the difference between that and the total hardness will represent the temporary hardness.

Say, 50 c.c. of the water thus treated required 1·6 c.c. of soap solution. Deducting 0·2 c.c. for lather, we get 1·4 c.c. and $1·4 \times 2·5 \times 2 = 7$ mgms. of calcium carbonate present in 100 c.c. of the water, and these 7 mgms. $CaCO_3$ represent the permanent hardness of 100 c.c. (100,000 mgms) of the water sample, or, in other words, 7 parts per 100,000 of permanent hardness.

The total hardness was 11 parts per 100,000, therefore the *temporary hardness* equals $11 - 7 = 4$ parts per 100,000.

The total hardness of a water should not exceed 30 parts per 100,000, otherwise it is unsuitable for domestic purposes. What are called hard waters vary from 20 to 30 degrees on the metrical scale, a soft water from 8 to 15, while a very soft water may contain up to 6 or 8.

The permanent hardness should not exceed 6 parts per 100,000. Of course the greater the proportion of temporary to permanent hardness, the better, since the former is, to a large extent, remediable, while the latter is not.

The Estimation of the Ammonia in a Water Sample.

This and the following analytical procedures aim essentially at obtaining evidence of organic matter in water. The organic matter may be of either animal or vegetable origin, but in every case exhibits a natural tendency to resolve itself into simple parts, more particularly into ammonia and oxidized salts of nitrogen, such as nitrites and nitrates. The process known as that of Wanklyn, Chapman, and Smith, recognizes two kinds of ammonia, namely, the *free* or *saline* ammonia, and the *albuminoid* ammonia.

The free or saline ammonia represents the ammonia combined with carbonic, nitric, and other acids, and also what may be derived from urea or other easily decomposed substances.

The albuminoid ammonia is that which can be derived from the breaking up of organic matter by the addition of a solution

of strongly alkaline permanganate of potassium, and then boiling.

To estimate the ammonia in a water sample it is necessary to have the following solutions:—

(1) *Nessler's Reagent.*—This is a saturated solution of mercuric iodide in potassic iodide. It gives a yellowish tinge, with the faintest trace of ammonia, passing, if much ammonia is present, to the formation of a yellow-brown precipitate of the di-mercurammonium iodide. Nessler's solution is prepared by dissolving 35 grms. of potassic iodide in 100 c.c. of distilled water. Also dissolve 13 grms. of mercuric chloride in 700 c.c. of distilled water, and mix the two solutions. Add cold saturated solution of mercuric chloride until a precipitate of the red periodide of mercury just begins to be permanent. The liquid must then be left to cool, and may with advantage stand for a few hours before being rendered alkaline. This is done by adding 160 grms. of solid caustic potash or 120 grms. of solid caustic soda to the liquid, which is afterwards to be diluted with distilled water, so that the whole volume of the solution may equal 1 litre. In order to render the Nessler reagent sensitive, it is mixed finally with a little more cold saturated solution of corrosive sublimate, and allowed to settle.

(2) *A standard solution of Ammonium Chloride.*—Ammonium chloride, represented by the formula NH_4Cl, bears a ratio to ammonia, as represented by NH_3, of as 53·5 is to 17. Therefore if 0·03147 grm. of ammonium chloride be dissolved in 1 litre of distilled water, that solution will be equivalent to 0·01 grm. of ammonia, and 1 c.c. of this solution will equal 0·01 mgm. of ammonia.

(3) *An alkaline permanganate of potash solution* made by dissolving 200 grms. of caustic potash and 8 grms. of potassium permanganate in 1100 c.c. of distilled water, and then rapidly boiling the solution down to 1 litre or 1000 c.c.

To determine the Free Ammonia, place 250 c.c. of the water sample in a retort and connect with a condenser. Apply heat to the retort and rapidly distil over the retort contents, catching the distillate in a series of Nessler glasses. When three Nessler glasses are thus filled up to their 50 c.c. marks, a fourth is placed to catch the distillate while 1 c.c. of Nessler's reagent is added to each of the first three glasses. If these glasses be placed from left to right in the order in which they received the distillate, the yellow tint created in each of them by the reagent will show a decrease from left to right, because the first 50 c.c. collected will contain the most free or saline ammonia, and the third the least. If there is no colour in the third or last glass, then all the

ammonia will have come over. If, however, the colour is at all distinct in the third glass, a fourth must be collected and tested in the same way. As a rule, all the free ammonia comes over in the first 150 c.c. of the distillate.

The colour in the glasses is caused by the presence of ammonia, the precise amount of which we proceed to estimate in the following manner. To other Nessler glasses are added varying quantities of the standard ammonium chloride solution, each made up to 50 c.c. with distilled water and 1 c.c. of Nessler's reagent added. When a tint exactly corresponding with that given by the respective 50 c.c. of the water distillate in the presence of 1 c.c. of Nessler's solution has been obtained, the quantity of standard ammonium chloride solution added is read off. This procedure of noting and comparing tints as given by different amounts of ammonia with Nessler's reagent is called "Nesslerizing."

The presence and degree of colour must be judged always by looking down through the depth of the water in a glass placed upon a white surface. If the tint given by the first 50 c.c. of distillate be very deep or exceed the value of 3 c.c. of the standard ammonium chloride solution, it is often difficult to judge accurately its comparative value, unless it be diluted either with ammonia free distilled water or by adding it to the less deeply tinted distillates in the other glasses, note being taken of the degree of dilution made.

Suppose, for example, that from 250 c.c. of water placed in the retort, 150 c.c. of distillate were collected in three glasses, the Nessler reagent added, and the last 50 c.c. or contents of third glass are found to contain no trace of ammonia. The whole of the free ammonia in the 250 c.c. of water has therefore been collected in two Nessler glasses. Assume that it was necessary to add 2 c.c. of the standard solution of ammonium chloride to the comparison test-glass, in order to match the colour in the glass containing the first 50 c.c. of distillate, and 1 c.c. of the standard solution was needed to match the tint in the second 50 c.c. of distillate. The total amount, then, of free ammonia yielded by the 250 c.c. of water corresponds to the ammonia present in 3 c.c. of the standard solution. But, as each cubic centimetre of the standard solution contains 0·01 mgm. of ammonia, therefore 3 c.c. contain 0·03 mgm. of ammonia: this, multiplied by 0·4 or divided by 2·5, gives 0·012 mgm. of free ammonia in 100 c.c. of the sample or parts per 100,000.

To determine the Albuminoid Ammonia.—To the residue left in the retort, employed in the last process, add 25 c.c. of the alkaline permanganate solution and 25 c.c. of ammonia free distilled water. Proceed to distill over as before, and continue

to do so until no more ammonia comes over. This ammonia is the so-called albuminoid, due to the breaking up of any organic matter present in the water under the influence of an oxidizing agent in the presence of a caustic alkali. The determination of the ammonia in this case is conducted in precisely similar fashion as for the free ammonia.

Say, in this case, it is found necessary to distil over 200 c.c. in four Nessler glasses before all the ammonia had come over. Assume that the fourth glass of distillate had a colour equal to 0·5 c.c. of the standard solution, the third to 1 c.c., the second to 2 c.c., and the first to 2·5 c.c. The sum of these amounts represents that 6 c.c. of the standard solution were required to match the colour furnished by the albuminoid ammonia in 250 c.c. of water. But as each cubic centimetre of the standard solution equals 0·01 mgm. of ammonia, therefore 6 c.c. equal 0·06 mgm.; in other words, there are 0·06 mgm. of albuminoid ammonia in 250 c.c. of water, or 0·024 mgm. in 100 c.c. or parts per 100,000.

In this process, before adding the alkaline permanganate solution to the residue in the retort, it is as well to boil it (the permanganate) for five minutes in order to get rid of any traces of ammonia which may be in it.

In drinking water, the free ammonia should not exceed 0·005 per 100,000, and the albuminoid ammonia not exceed 0·01 per 100,000. The presence of much free ammonia with excess of chlorine, nitrites and nitrates, usually denotes animal pollution. Much albuminoid, with a small amount of free ammonia, indicates vegetable contamination, particularly so if the chlorides, nitrites, and nitrates are low. Rain water often contains a large amount of free ammonia, probably derived from soot, and appears to be harmless. Deep wells often show much free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would be very suggestive of sewage or at least urine.

Estimation of Nitrites in a Water Sample.

When organic matter putrefies or decomposes, it becomes reduced to its absolute elements. Of these nitrogen is the chief, and this combining with hydrogen forms first ammonia; hence the presence, more or less, of free or saline ammonia in a water when at all polluted with organic matter, such as raw sewage. In the course of time, or as it percolates through the soil, the ammonia in the water acquires oxygen, and gradually becomes partially oxidized to nitrous acid, HNO_2, or to nitric acid, HNO_3, which acids, by combining with bases like calcium, sodium, or

potassium, form *nitrites* and *nitrates*. The oxidation of organic matter cannot go beyond the formation of nitric acid and nitrates, while the nitrous acid and nitrites mark an intermediate stage of imperfect oxidation.

The determination of nitrites and nitrates in a water is important as indicating either a pollution at some remote period with possibly dangerous matter, or more recently with a partially or completely oxidized sewage. Waters fouled by vegetable matter yield, as a rule, little nitrite or nitrate, chiefly because not only does vegetable decomposition yield relatively little nitrogen, but also because the natural tendency of all plant life is to remove both nitrites and nitrates from a water.

To determine the Nitrites, we require the following three solutions :—

(1) *Dilute sulphuric acid*, consisting of one volume of strong acid to two of distilled water.

(2) *A solution of meta-phenylenediamine*, made by dissolving 5 grms. of meta-phenylenediamine in a litre of distilled water, rendered acid with sulphuric acid. This should be decolourized, if necessary, by filtering through animal charcoal.

(3) *A milli-normal standard solution of potassium nitrite.*—Owing to the unstable nature of this salt, it is necessary to prepare it specially for making up this solution. By the following chemical equation, $\underset{154}{AgNO_2} + \underset{74\cdot5}{KCl} = \underset{143\cdot5}{AgCl} + \underset{85}{KNO_2}$, it is seen that 154 parts of pure silver nitrite in the presence of 74·5 parts of potassium chloride are decomposed with the formation of 143·5 parts of silver chloride, and 85 parts of potassium nitrate or 46 of nitrous acid as represented by NO_2. Hence, if 1·54 grms. of pure silver nitrite be dissolved in hot water, decomposed with a slight excess of potassium chloride, allowed to cool, made up to a litre, we obtain a $\frac{N}{100}$ solution of potassic nitrite, equalling 0·46 grm. of nitrous acid as NO_2. If each 100 c.c. of this solution after standing, and subsidence of the silver chloride, be again diluted up to a litre with distilled water, we get a $\frac{N}{1000}$ solution of KNO_2, equalling 0·046 grm. of NO_2, and each cubic centimetre of which equals 0·046 of a milligramme of NO_2.

The **Process** consists in placing 50 c.c. of the water sample in a Nessler glass and adding thereto 1 c.c. of both the dilute sulphuric acid and meta-phenylenediamine solutions; if an orange colour is produced immediately, the tint will prove too deep for comparison, and another trial must be made with 25 c.c. of the water diluted up to 50 c.c. with distilled water, when probably

only a faint colour will be perceived. The object of this preliminary trial is to find out the amount of water which can be used in the experiment; the proper amount is that which gives only a faint trace of colour on the addition of the reagents. Having decided the amount which can be used, it must, if less than 50 c.c., be diluted up to this amount with distilled water, and then placed in a Nessler glass. Trial glasses containing different amounts of the standard nitrite solution diluted up to 50 c.c. with distilled water are then made. One c.c. of the dilute sulphuric acid and 1 c.c. of the meta-phenylenediamine are next added to the Nessler glass containing the water to be examined and to each of the trial glasses as quickly as possible, so that the colours in them may develop from exactly the same time. The glasses are compared at the end of ten to fifteen minutes, and the amount of standard solution determined, which gives the same colour as the nitrite in the water under examination. If the tints are not matched exactly at the first time, a second attempt must be made, all the glasses being filled again at exactly the same time. The standard potassium nitrite, being of the strength of 1 c.c. = 0·046 mgm. of NO_2 or nitrogen tetroxide, the number of cubic centimetres used gives the milligrammes of NO_2 present in the sample of water. Assuming that 2 c.c. of the standard potassium nitrite are placed in a Nessler glass, made up to 50 c.c. with distilled water, receive 1 c.c. each of dilute acid and meta-phenylenediamine, and the same shade of tint obtained as that yielded by 25 c.c. of water sample after dilution to 50 c.c. and the addition of 1 c.c. each of dilute acid and meta-phenylenediamine; then $2 \times 4 \times 0·046 = 0·368$ mgm. NO_2 in 100 c.c. of water or parts per 100,000: multiplying this by $\frac{N}{NO_2}$ or $\frac{14}{46}$, we get the equivalent in terms of nitrogen.

It may be accepted as a good rule that no water which shows the presence of nitrites is fitted for domestic use.

Estimation of Nitrates in Water Sample.

A process which is both simple and satisfactory is that known as the phenol-sulphuric acid method: for it the following solutions are required:—

(1) *Phenol-sulphuric acid*, made by adding 6 grms. of pure phenol and 3 c.c. of distilled water to 37 c.c. of strong sulphuric acid free from nitrates.

(2) *Standard solution of potassium nitrate*, made by dissolving 0·0722 gram. of recently fused potassium nitrate in water, and the solution subsequently made up to a litre. One c.c. of this solution will contain 0·01 mgm. of nitrogen.

The process is thus performed: 10 c.c. of the water under examination and 10 c.c. of the standard potassium nitrate solution are evaporated separately just to dryness in two porcelain or platinum dishes. To each of the residues, 1 c.c. of the phenol-sulphuric acid is added and thoroughly mixed by means of a glass rod. If the water under examination contains a large amount of nitrates, the liquid will quickly turn red; if it contains but a small quantity, this colour will not appear for about ten minutes. After the dishes have stood from ten to fifteen minutes, their contents are washed out successively with 25 c.c. of distilled water into two clean Nessler glasses, about 20 c.c. of liquor ammonia (sp. gr. 0·96) added, and both made up to 100 c.c. with more distilled water.

Any nitrate present in the solutions converts the phenol-sulphuric acid into picric acid, which, by the action of the ammonium, forms ammonium picrate: this gives a yellow colour to the solution, the intensity being proportional to the amount present.

The colours of the two solutions are now compared, and the darker one diluted until the tints are adjusted, the calculation being made as explained in the preceding tests for nitrites.

Suppose 10 c.c. of the sample and 10 c.c. of the standard nitrate solution have, after treatment and dilution each to 100 c.c., given two shades of yellow, that from the standard solution being the darker. This, on dilution to 200 c.c., is still found to be too dark, but this, again on further dilution to 900 c.c., gives the desired match in colour. As the 10 c.c. of standard solution originally treated equal 0·1 mgm. of nitrogen, then $900 : 100 :: 0{\cdot}1 : x = 0{\cdot}011$ mgm. of nitrogen in 10 c.c. of the water sample, or 0·11 part of nitrogen from nitrates per 100,000. If expressed as NO_3, this equals 0·43 per 100,000.

In the case of very pure waters, it is better to evaporate down 20, 50, or more c.c. of the sample, and only 5 c.c. of the standard nitrate solution. Conversely, if the sample be rich in nitrates, it must be diluted down with distilled water.

No water used for drinking purposes should contain more than 0·35 part per 100,000 of nitrogen in the form of nitrates, unless, of course, the geological strata are such as can be legitimately regarded as the source from which the water derives these salts.

Estimation of the Oxygen Consuming Power of a Water Sample.

Although by itself of little value as a measure of the organic impurity, still the power of consuming or affinity for oxygen which

a water sample has, when taken in conjunction with other analytical facts, is often a material aid in forming an opinion as to the quality of any particular water. Much of the organic matter present in water is capable of oxidation, but since the ease of oxidation bears no constant ratio to the nature of the organic matter, its estimation affords no very reliable index to the real pollution present. In all the efforts to judge the oxidizable organic matter, advantage is taken of the fact that, in the presence of organic substances, permanganate of potassium, $KMnO_4$, freely parts with its oxygen until all the permanganate has been reduced to hydrated manganese dioxide: thus, $2(KMnO_4) = K_2MnO_4 + MnO_2 + O_2$: in everyday life, this change is marked by the pink colour which this salt originally gives to water being replaced by a brown. Unfortunately, different substances reduce different proportions of permanganate, and slight variations in temperature and acidity or alkalinity materially influence the readiness with which the permanganate parts with its oxygen.

To determine the Oxidizable Organic Matter, use is best made of what is known as Tidy's process. This process is based upon the chemical fact that in the presence of an acid and heat, the following decomposition of permanganate takes place:— $4(KMnO_4) + 6(H_2SO_4) = 2(K_2SO_4) + 4(MnSO_4) + 6(H_2O) + 5O_2$, or, in other words, 632 parts of potassium permanganate yield in the presence of sulphuric acid 160 parts of oxygen.

For Tidy's process, the following solutions are necessary:—

(1) *Standard potassium permanganate solution.*—Since 632 parts of the salt with an acid yield 160 parts of oxygen, then 0·395 grm. of potassium permanganate, if dissolved in a litre of water, will be equivalent to 0·1 grm. of oxygen. This constitutes the standard solution, and 1 c.c. of it used with acid yields 0·1 mgm. of oxygen.

(2) *Potassium iodide solution.*—A 10 per cent. solution in distilled water.

(3) *Sodium thiosulphate solution.*—One grm. dissolved in a litre of distilled water.

(4) *Starch solution.*—One grm. of starch, mixed with $\frac{1}{2}$ litre of distilled water, boiled for five minutes and filtered.

(5) *Dilute sulphuric acid*, consisting of one volume of strong acid to three of distilled water.

In performing this process, Tidy recommended two determinations to be made, namely, one of the oxygen absorbed after fifteen minutes' exposure at a temperature of 80° F., and one after four hours' exposure at the same temperature. He considered that during the first quarter of an hour, the more or less putrescent

easily oxidized animal organic matters were oxidized, while the oxidation of the vegetable organic material did not take place till after four hours or so. Practically, as much information as can be gained is obtained at the end of fifteen minutes; therefore, except in special cases, the second observation after four hours is hardly necessary. If required, it is performed exactly in the same manner as the shorter exposure.

Into a stoppered bottle, capable of holding from 300 to 400 c.c., place 250 c.c. of the water sample, and heat in a water-bath to 80° F. (26°·7 C.); when the required temperature is reached, run in 10 c.c. of the dilute sulphuric acid and 10 c.c. of the permanganate solution. A pink colour will result. Maintain the bottle contents at 80° F., carefully noting whether the pink tint is discharged; if the tint disappear, add more permanganate. At the end of fifteen minutes, add to the water three drops of the iodide of potassium solution. Owing to there being a certain amount of oxygen available from the permanganate, as previously explained, this will liberate iodine from the iodide, with the result that the pink-coloured bottle contents will now become yellow: thus, $5O_2 + 20KI + 10H_2O = 20KHO + 10I_2$. The quantity of iodine set free will, of course, be dependent on the amount of potassium permanganate remaining unreduced in the water. If the iodine set free is absolutely dependent upon the amount of permanganate left unreduced by the organic matter in the water, it is obvious that any estimation of the iodine liberated will be a measure of the unused oxygen, and this deducted from what was rendered available by the original quantity of permanganate added, will give a measure of the oxidizable organic matter in the 250 c.c. of water.

We proceed to make these estimations in the following manner: To the iodine-tinted water, the thiosulphate solution is gradually added with the object of reducing it: thus, $I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$. In order to know exactly when all the free iodine has been removed from the water, an indicator in the form of 1 c.c. of the starch solution is added; this, so long as any free iodine is present, will give a blue tint. Therefore, continuing the addition of the thiosulphate, we stop the moment all the blue colour has gone, and read off the actual amount of thiosulphate used.

Unfortunately, thiosulphate of soda is a very unstable salt, and its particular value as a reducing agent needs to be judged, at the time of each experiment, by means of a control observation of its power upon an identical quantity of permanganate in distilled water, as was used for the unknown sample. Accordingly, into a similar bottle, 250 c.c. of distilled water are placed, heated to 80° F., 10 c.c. of the dilute sulphuric acid, and exactly

the same amount of permanganate as was used for the water sample added, and the whole kept at 80° F. for fifteen minutes. In this bottle, owing to there being no organic matter, practically the whole of the oxygen liberated from the permanganate under the circumstances will be unconsumed, and consequently, on the addition of three drops of potassium iodide, more iodine will be liberated, and more of the thiosulphate will be required to reduce it. The iodide, the starch, and the thiosulphate are added precisely as in the other experiment.

So soon as all the iodine has been removed, as shown by the disappearance of the blue colour, the amount of thiosulphate used is read off; its volume will represent, for the time being, the actual reducing value of the thiosulphate for the precise amount of permanganate used or added in the experiment. And the difference between the amount of thiosulphate solution needed to reduce the x amount of potassium permanganate in this pure distilled water, and that required for the same amount which has been more or less decomposed or reduced by oxidizable organic matter in the water sample, will represent the quantity of oxygen consumed by such oxidizable matter.

Example.—Say 10 c.c. of $KMnO_4$ in the distilled water has used up 40 c.c. of the thiosulphate solution; therefore 40 c.c. of the thiosulphate may be considered as equivalent to 10 c.c. of permanganate, or 1 mgm. of oxygen, because each cubic centimetre of $KMnO_4$ equals 0·1 mgm. of oxygen.

Another 10 c.c. of $KMnO_4$, in the unknown water sample, used up, say, 32 c.c. of the thiosulphate solution; therefore an amount of oxygen equivalent to the difference between 40 and 32 or 8 c.c. of the thiosulphate solution has been taken up by the organic matter. But if 40 c.c. of thiosulphate equal 1 mgm. of oxygen, then 8 c.c. equal 0·2 mgm. of oxygen. This means that 0·2 mgm. of oxygen is taken up by 250 c.c. of the water sample, or parts per 250,000; this multiplied by 0·4 equals 0·8 parts of oxygen consumed by the organic matter per 100,000.

In performing this process, the permanganate added must be sufficient to create a pink colour, which remains distinctly permanent at the end of the heating. If the four-hour test be applied, it may be necessary to make repeated additions of the permanganate solution. The *total* quantity actually used must be carefully noted, and the same amount of course employed in the distilled water experiment.

In endeavouring to interpret the results of the oxygen process, it must be borne in mind that besides organic matter, iron salts, nitrites, and sulphuretted hydrogen will reduce permanganate of potassium, and these latter, if present, must be duly allowed for.

It is difficult to distinguish between the oxygen consumed by the nitrogenous and the non-nitrogenous organic matter. Roughly speaking, the four-hour experiment gives information as to the total amount of oxidizable organic matter, while the fifteen-minutes' reaction is valuable as indicating the proportion of putrescent or readily oxidizable and presumably dangerous material. Peaty waters consume large quantities of oxygen; hence, as in all other attempts to measure the organic matter in a water sample, the results of the oxygen process must be considered in conjunction with the other analytical data and the source of the water.

In a general way, it may be said that waters of great organic purity will not consume more than 0·05 of oxygen per 100,000 in fifteen minutes at 80° F., and that when the oxygen consumed exceeds 0·1 per 100,000, the sample may be considered of doubtful purity.

Determination of Dissolved Oxygen.

This estimation in connection with the examination of waters and sewage effluents is occasionally needed, but for practical purposes the method must be simple, speedy, accurate, and not require large quantities of the sample. A further condition is that the waters must not be subjected to a diminished oxygen pressure, *i.e.* must not be operated upon in an atmosphere of inert gas, otherwise there might be a rapid loss by diffusion. Several methods for determining the dissolved oxygen in water have been proposed: the chief objection to them has been the necessity of special apparatus. As being, perhaps, the most simple and readily applied we here describe a method suggested by Winkler.

The following solutions are required for the process:

(1) *Manganous chloride solution*, made by dissolving 80 grms. of $MnCl_2.4H_2O$ in 100 c.c. of distilled water. The solution must be free from iron.

(2) *Potassium iodide and caustic soda solution.*—Dissolve 10 grms. of iodide of potassium in 100 c.c. of a 33 per cent. solution of pure caustic soda. This solution when diluted with water and acidified with sulphuric acid ought not to give any colour with a solution of starch.

(3) *Centi-normal solution of iodine*, made by dissolving 1·27 grms. of pure dry iodine and 2 grms. of iodide of potassium in 20 c.c. of distilled water, and then making up to 1 litre with distilled water.

(4) *Centi-normal solution of thiosulphate of soda*, made by dissolving 2·48 grms. of pure dried $Na_2S_2O_3.5H_2O$ in a litre of

distilled water. This solution must be kept in the dark and in a cool place: as its value tends to alter, it should be titrated before use with the above iodine solution, diluted with water and in the presence of some starch solution; ten c.c. of the iodine solution should require 10 c.c. of the thiosulphate solution for decolourization.

(5) Starch solution as prepared for the estimation of oxygen consuming power of a water.

The **Process** is as follows: Take a glass bottle provided with a well-fitting glass stopper, and having approximately a capacity of 300 c.c. Determine accurately the capacity of the bottle. Wash out the bottle thoroughly with some of the water to be examined, and then fill it to overflowing. Introduce, by means of a graduated pipette, having a long narrow point, 1 c.c. of the iodide and soda solution, and also 1 c.c. of the manganous chloride solution. Do this carefully and gradually, so that the point is close to the bottom of the bottle. Put in the stopper tightly, and see that no air-bubbles remain. Mix the contents by swinging the bottle lightly round; allow the precipitate which forms to settle down; if it does not readily settle, the bottle should be allowed to stand for an hour or so, but taking care that no air gains access to the bottle contents. When the precipitate has settled down and the fluid in the upper part of the bottle is clear, introduce carefully down the side, by means of a pipette, from 3 to 5 c.c. of fuming hydrochloric acid (sp. gr. 1·16 to 1·18), so as to let it fall on to the precipitate; replace stopper, and swing the bottle gently round until the precipitate dissolves. The iodine-tinted fluid in the bottle is now washed out into a clean beaker with distilled water, and then titrated in the presence of starch with the thiosulphate solution, 1 c.c. of which equals 0·0000798 grm., or 0·055825 c.c. of oxygen. The iodine liberated corresponds to the oxygen present in the water, therefore the cubic centimetres of thiosulphate used multiplied by 0·055825 give the cubic centimetres of oxygen present in the original volume of water placed in the bottle, less two or whatever volumes of the iodide and manganous solutions have been added. The various chemical reactions which take place in the process may be expressed by the following equations:—

$$2MnCl_2 + 4NaOH = 4NaCl + 2Mn(OH)_2$$
$$2Mn(OH)_2 + O + H_2O = 2Mn(OH)_3$$
$$2Mn(OH)_3 + 6HCl = 2MnCl_3 + 6H_2O$$
$$2MnCl_3 + 2KI = 2MnCl_2 + 2KCl = I_2$$

Example.—Say the capacity of the bottle was 280 c.c. After the necessary manipulations had been made, assume that 32·9 c.c.

of the thiosulphate solution were used to decolourize the iodized water. This will represent 1·8366 c.c. of oxygen in 278 c.c. of water, or 6·6066 c.c. in 1 litre. A correction for temperature and pressure is not necessary.

It must be borne in mind that this process needs to be done rapidly and at once; it is also interfered with by the presence of much organic matter which absorbs the liberated iodine, and by the presence of nitrites which when acidified set free iodine. Such interference can be prevented to a great extent by working very rapidly and using as little starch as possible. The amount of dissolved oxygen in a water is influenced largely by temperature, being less in summer and greater in winter. Roscoe and Lunt give the following figures as representing the cubic centimetres of oxygen in a saturated water at different temperatures; namely, at 5° C. 8·68, at 10° C. 7·77, at 15° C. 6·96, and at 20° C. 6·28. Ordinary tap-water in this country contains on an average 7 c.c. of dissolved oxygen per litre; this is about 1 part by weight per 100,000.

Estimation of Lead in a Water Sample.

The only metal that is likely to require quantitative determination is lead. Before making this estimation, it must be first ascertained that the darkening produced by ammonium sulphide is really due to lead, not to iron or copper.

The reagents required are (1) a saturated solution of ammonium sulphide, and (2) a standard solution of lead acetate, made by dissolving 0·1831 grm. of crystallized acetate of lead, $Pb(C_2H_3O_2)_2 \cdot 3H_2O$, in 1 litre of distilled water. Each cubic centimetre of this solution contains 0·1 mgm. of metallic lead.

The **Process** consists in first evaporating 200 c.c. of the water sample down to 100 c.c., and placing the same in a colour comparison or Nessler glass on white paper. Add three drops of the ammonium sulphide solution. Note if any darkening is produced. Into a similar Nessler glass put 1, 2, or more c.c. of the standard lead solution, make up to 100 c.c. with distilled water, add three drops of the ammonium sulphide solution, and match the dark colorations. Calculate the amount found in parts per 100,000, and in grains per gallon.

Thus, for example, presume water concentrated from 200 to 100 c.c gave a colour equal to 3 c.c. of standard lead solution, with three drops of ammonium sulphide solution. Then $3 \times 0{\cdot}1 = 0{\cdot}3$ mgm. of lead in the 100 c.c. of water; but this equals or represents 200 c.c. of the original water, therefore, in each 100 c.c. there are 0·15 mgm. of lead, or 0·15 cgm. in a litre (parts per

100,000); this multiplied by 0·7 = 0·105 gr. per gallon, or rather more than $\frac{1}{10}$ gr. of metallic lead per gallon.

Many waters, especially those that are soft and peaty, and therefore liable to act on lead, often possess sufficient colour to equal 0·5 or even 1 c.c. of the lead solution; if this is the case, compare its colour with that produced by a given quantity of lead solution in the presence of three drops of ammonium sulphide, and make any needful deduction accordingly. Care must be taken not to clear the water by filtration, as ordinary filter-paper removes an appreciable quantity of lead.

No drinking water should contain lead, but $\frac{1}{20}$ gr. per gallon may be placed as the extreme permissible limit.

Estimation of Iron in a Water Sample.

This quantitative determination is occasionally required, and can be conveniently performed by the following process, for which these solutions are needed:—

(1) *A standard solution of ferric sulphate*, made by dissolving 0·0496 grm. of ferrous-sulphate in a litre of distilled water, acidifying with sulphuric acid, and adding sufficient potassium permanganate to make a faint pink colour. One c.c. of this solution contains 0·01 mgm. of iron.

(2) *Dilute nitric acid.*—Dilute 30 c.c of pure concentrated nitric acid with distilled water to measure 100 c.c.

(3) *A solution of potassium sulpho-cyanate*, made by dissolving 15 grms. in 100 c.c. of distilled water.

The **Process** is as follows: Acidify 50 c.c. of the sample with 0·5 c.c. of hydrochloric acid, and add just sufficient of dilute potassium permanganate solution to convert any iron which may be present to the ferric state. Next evaporate this pink-tinted water nearly to dryness in order to drive off any excess of acid, and then dilute to its original volume of 50 c.c. with distilled water. Into each of two Nessler glasses place 5 c.c. of the dilute nitric acid and 5 c.c. of the sulpho-cyanate solution. To one of these glasses add a measured quantity of the treated water sample, and then fill both glasses up to 50 c.c. mark with distilled water. If any iron be present in the treated water sample, a blood-red colour will be produced in the glass to which a measured volume was added. Into the other glass some of the standard iron solution is added until the colours in both agree or coincide in tint. The precise amount of the treated water sample to be added to the first glass will depend upon the quantity of iron present; but, as a rule, not more should be used than will require 2 c.c. of the standard iron solution to match it in colour, otherwise the tint

produced will be too deep for accurate comparison. The subsequent calculation is obviously simple, as each cubic centimetre of iron solution represents 0·01 mgm. of iron. The result can be expressed either as parts per 100,000 or grains per gallon.

EXAMINATION OF SUSPENDED MATTER AND DEPOSIT.

Where a sediment forms from a sample of water, it is desirable to take advantage of the valuable evidence which a microscopic examination affords. The most simple method by which the deposited matter can be collected and examined is the following: After well shaking, pour from half to one litre of the sample into a large conical glass, cover it over, and set aside for twenty-four hours; then decant or siphon off as much of the supernatant water as it is safe to do without disturbing the deposited matter at the bottom of the glass. Some of this sediment should then be taken up by means of a small pipette, and transferred to several glass slides, cover glasses applied, and the examination by the microscope proceeded with, any excess of water upon the slide being removed by clean blotting-paper. The various forms of animal and vegetable life, and of inanimate organic and inorganic material, are best sought by commencing with a low-power lens, say 1 inch, and then passing on to the $\frac{1}{4}$-inch power. The steps necessary for examining the bacterial contents of a water sample are dealt with in a subsequent section.

The nature of the suspended matter varies greatly, embracing such diverse objects as mineral grit, sand, flint, chalk, and mica particles, woody fibre, fragments of leaves, starch cells, macerated paper, amorphous vegetable *débris*, hairs, feathers, down, cotton, wool, or silk fibres, and scales or wings from various insects. The foregoing are all inanimate, but in addition there is often much animate vegetable material, such as fungi, either as spores or mycelia, and numerous forms of algæ, as well as living animal forms, such as protozoa, rhizopoda, infusoria, crustacea, insects, worms and their ova or eggs. The presence of the spores and mycelia of the higher fungi indicates impurity probably derived from sewage, since the latter usually contains phosphates, without which these forms cannot live. Algæ, diatoms, and desmids are common in open wells, lakes, ponds, and streams; they are not an infrequent cause of the peculiar odour developed in such waters. The lower forms of animal life are only found in waters containing organic matter in solution. This material may be derived from decaying vegetable matter. The higher forms of life do not necessarily denote impurity, but the presence of worms or of their ova and embryos is particularly objectionable, since they may be forms

which can develop in the human body, and give rise to ill effects.

The most suspicious elements which may be detected by a microscopical examination of water sediment are those which point directly or indirectly to the waste products of man. Among the latter are cotton, wool, hair, and linen fibres, while the former include substances which leave the body in the fæces owing to their indigestibility. Under this heading may be mentioned fat cells, starch grains, muscle fibres, various connective tissue elements, shreds of membrane, epithelial cells, fragments of food, and the various parasitic worms either as ova or mature forms.

THE BACTERIOLOGICAL EXAMINATION OF WATER.

No attempt is made in this section to give a complete study of this difficult and complicated question; but merely the presentation of the more important facts, and the outline of a working scheme for the routine biological examination of waters, upon which the student, by a further study of the special literature of the subject, can build a more elaborate and complete procedure. It is also assumed that no one will attempt the bacteriological examination of a water sample who has not acquired a knowledge of the necessary experience and technique in a suitably equipped laboratory under the guidance of a competent teacher. For these reasons it is deemed unnecessary to either describe the apparatus to be found in every laboratory, or to enter into details of the comparatively simple technique used in the routine methods of bacteriological work.

We would say, however, that the bacteriological examination of a water sample constitutes an essential complement to its chemical analysis, and that the latter without the former affords at best but an imperfect gauge as to the freedom of a water from organic contamination. Bacteriological examinations of water samples are mainly undertaken either for testing the efficiency of filter-beds or for the direct detection of pollution from manure or sewage. This information upon which such opinions or conclusions can be based is practically of the following three kinds:—

(1) A quantitative estimation of the number of micro-organisms present in the sample of water under examination.

(2) The detection of micro-organisms not necessarily hurtful to man, but whose presence and origin imply that the sample is more or less contaminated with fæcal or manurial pollution.

(3) The isolation and identification of actual disease-producing organisms. The smaller the volume of water in which the

micro-organisms under the second and third headings can be detected the greater the pollution, and *vice versâ*.

Collection and Transmission of Samples.—This constitutes a very important procedure, and any carelessness displayed is liable to seriously vitiate the results. The sample should be collected in glass bottles with glass stoppers, previously sterilized at 150° C. for three hours. If sterilization by heat is not feasible, the bottles may be cleaned sufficiently by washing them out with a little pure sulphuric acid, all traces of acidity being removed by rinsing the bottle thoroughly with some of the water to be examined. In the case of rivers, ponds, or lakes, the bottle should be plunged below the surface before the stopper is removed; in this way a sample of the main body of water will be obtained. In some cases, as when the presence of the cholera organism is suspected, it is desirable to examine the surface water. If the source of water is a piped supply, the tap should be opened and the water allowed to run to waste for a few minutes before the sample is collected. It is always desirable, in the case of piped supplies, to obtain, if possible, a sample direct from the main. In the case of wells, particularly if not in constant use, it is advisable to pump continuously for a few hours before collecting the sample for examination. In all cases, after the specimen has been obtained, the glass stopper should be quickly replaced and carefully tied down with a little oiled silk. The next point is to have the sample examined as quickly after collection as possible. If the specimen cannot be examined at once, it should be packed in ice, and then transmitted to the laboratory. The importance of keeping the sample in the cold is based upon the fact that when the temperature is kept below 5° C., there is practically no increase in the number of micro-organisms in the water.

For the transmission of samples intended for bacteriological examination, special boxes or carriers are usually employed; these contain one or more glass-stoppered bottles of about eight-ounce capacity, fitting into a tin-lined receptacle, and into which they are carefully secured by a close-fitting lid. This tin case containing the bottle or bottles is surrounded by a metal receptacle for holding ice, this again being surrounded by a thick layer of asbestos and felt, the whole being contained in a strong wooden box or case having a well-adjusted, felt-lined lid, and capable of being securely fastened and locked. In transmitting these carriers to the laboratory, it is of the first importance to do so by the most expeditious route, so as to avoid all possible delay. Full particulars as to the nature and source of the sample should invariably accompany the carrier, as without such information it is difficult to give a satisfactory opinion regarding its hygienic condition.

The Quantitative Examination.—The determination of the number of micro-organisms in a known volume of water is effected mainly by cultures on solid media, such as gelatine or agar. The method consists in adding varying quantities of the water to tubes of liquefied gelatine or agar: each of these is then thoroughly mixed and poured with suitable precautions into a sterile Petri dish, and solidified as rapidly as possible. These water-plates are then incubated, the gelatine at 20° C. and the agar at 37° C. Each organism present, capable of development under the existing conditions, develops into a mass or colony of bacteria, visible to the naked eye, and as such readily counted. The total number of colonies found gives the number of organisms capable of development in the medium used, and at the particular temperature of incubation.

The amount of water to be added to the media tubes varies with the suspected degree of pollution; for ordinary waters 0·1 to 0·5 c.c. are routine quantities to add to gelatine tubes, and from 0·5 to 1 c.c. to agar tubes. With dirty waters, these amounts will be too large, and greater dilution must be practised. For inoculating the gelatine or agar tubes before plating, 1 c.c. pipettes graduated in one-hundredths of a cubic centimetre are employed, the pipette, after thorough cleaning and plugging of the upper end with cotton wool, being carefully sterilized before use. For enumeration of the colonies, it is convenient to count with the plate on a dark background, dividing the area by lines marked on the plate itself. When plates are very crowded, it may be possible to count colonies in only a few segments, deducing the total bacterial content from these data. Apart from difficulties due to overcrowding, enumeration of colonies on gelatine plates is often impossible owing to the presence of types which more or less rapidly liquefy this medium. The same difficulty arises if working in a hot climate, or under conditions in which solidification of gelatine is impossible. In these cases the routine employment of agar for making water-plates presents advantages, as liquefaction does not take place. But it must be borne in mind that if these plates are incubated at 37° C., the majority of water organisms are suppressed, and consequently the number of resulting colonies will be much smaller than on the gelatine incubated at from 20° C. to 22° C.

In regard to the number of micro-organisms present in waters derived from different sources, no hard-and-fast standards can be enunciated. A dirty water will contain many more organisms than a pure water, but the number in a pure supply may vary from 50 to 560 per cubic centimetre. When judging the efficiency of water filters, Koch laid down as a standard that satisfactory filtration

could not be accepted if the number of micro-organisms exceeded 100 in each cubic centimetre of filtrate. As a working basis this standard is adhered to by many observers. The value and importance attaching to the enumeration of the bacteria present in a given quantity of water has been variously appraised. For our own part, we do not think that it, in itself, furnishes information of any great importance. We are forced to this conclusion from the fact that the nature of the medium, its reaction, the duration and temperature of incubation, are all important factors in the development of water bacteria. It is well known that the reaction of the media used exercises a marked influence on the number of micro-organisms which develop. Until some authoritative standard is arrived at, and all observers agree to adhere to media of that standard reaction, it is difficult to compare results. The American workers recommend all media used in this class of work to be +1·5, that is, *acid* to the extent of 1·5 per cent. of normal acid, using phenol-phthalein as the indicator. The tendency in this country is to use a +1 per cent. standard, and is the reaction usually employed by ourselves. Again, there is no uniformity of practice as to duration and temperature of incubation. Some count only the colonies visible on the second day, others those visible on the third, fourth, or even fifth days; some enumerate only colonies visible to the naked eye, others use a lens or low power of the microscope for counting. It seems desirable to be very careful about stating that a given water contains a certain number of organisms per cubic centimetre, as any accurate determination of the kind is practically impossible. The most that should be said is, to state that 1 c.c. of the sample has yielded so many organisms on such and such medium of such a reaction, after so many days' incubation at a given temperature, taking care to add whether the colonies included only those visible to the naked eye, or all visible under a certain degree of magnification.

Qualitative Examination.—This embraces the isolation and enumeration of organisms not necessarily hurtful, but which from their origin are especially liable to be associated with contamination, also the isolation and identification of actual disease-producing organisms. Owing to the inherent difficulties in the way of isolating actually specific disease-producing bacteria from a water sample, it must be admitted that in the greater number of cases we have to rely mainly upon the detection of organisms associated with fæcal or manurial contamination, and although the various methods which have been suggested for this purpose are by no means perfect or completely satisfactory, still, if properly conducted, they may be relied upon to detect pollution, even to the extent of one part of recent sewage in a million parts of water.

When the pollution is less than this or when the contamination is far from recent, the bacteriological results usually suffice to raise grave suspicions of pollution, and, if supplemented by an inspection of the source of the water or a knowledge of its history, are sufficient to justify a definite opinion being formed and given. In the light of our experience, the qualitative bacterial method of examination of a water is about a thousand times more delicate than the chemical method.

A variety of procedures have been proposed for obtaining an indication of the presence or absence of organisms rarely present in waters of known purity, but which are invariably present in sewage-polluted samples. These procedures are based mainly upon the principle of either placing definite volumes of the water into media or under conditions which retard or inhibit the growth of the ordinary water organisms, and yet allow the sewage forms to develop, or placing the water sample into media which foster the growth of organisms of intestinal origin if present, rather than inhibiting the development of the ordinary water bacteria. The more practical methods, in our opinion, are those associated with the names of Parietti and MacConkey respectively. The former may be defined as an inhibitory method *quâ* ordinary water organisms, the latter as a fostering method *quâ* sewage organisms, and possibly also inhibitory as to other forms of microbes. As MacConkey's method is the more comprehensive, and certainly in our hands the more generally useful, we describe it first.

MacConkey's Method.

This consists in adding to varying quantities of the water sample a special medium, first suggested by MacConkey and Hill, namely, bile-salt glucose peptone litmus solution, and incubating at 42° C. for forty-eight hours. For the routine examination of waters, a concentrated stock solution should be prepared, made as follows: sodium taurocholate, 15 grms.; glucose, 15 grms.; peptone, 60 grms.; litmus solution, a sufficiency to give a deep purple tint; distilled water, 1 litre. This is boiled and filtered, and then, subject to certain dilutions as detailed hereafter, run in varying quantities into each of a number of clean test-tubes, in which also is a small inverted glass tube ($1\frac{1}{2}$ inch by from $\frac{1}{4}$ to $\frac{1}{2}$ inch). The outer tubes, after addition of the solution and plugging with cotton wool, are sterilized for fifteen minutes at 100° C. on three successive days. The degree of dilution of this stock solution required depends absolutely upon the volume of water sample to which it is to be added, as it is desirable that in each case the final dilution may contain approximately the same

proportion of the bile-salt and other constituents. For the practical application of this medium in the examination of waters, it is desirable to have the test-tubes of two sizes, namely, large ones measuring 8 inches by 1 inch, and smaller ones 6 inches long and $\frac{3}{4}$ inch in diameter. With them the following dilutions have been found to work well:—

(*a*) Into the large-sized tubes place 30 c.c. of the concentrated stock solution of bile-salt glucose peptone litmus solution, and sterilize in the usual way. To these 50 c.c. of the water to be examined may be added, and then incubated as explained.

(*b*) Dilute one volume of the concentrated stock solution with half its volume of distilled water, place 10 c.c. of this diluted solution into each smaller-sized test-tube, and sterilize. To each of these 10 c.c. of the water sample may be added, and then incubated as above.

(*c*) Dilute one volume of the concentrated stock solution with an equal volume of distilled water, place 10 c.c. of this diluted solution into each of the smaller-sized test-tubes, and sterilize. To each of these 5 c.c. of the water sample may be added, and then incubated.

(*d*) Dilute one volume of the concentrated stock solution with two volumes of distilled water, place 10 c.c. of this diluted solution into each of the smaller sized tubes, and sterilize. Each of these may then receive 2 c.c. or less of the water under examination and be incubated.

By this method we have a series of test-tubes containing varying strengths of the bile-salt solution, and, by the addition of varying volumes of the water to be examined, so diluted that they approximately all contain the same proportions of original constituents. Experience shows that the micro-organisms which can grow in this bile-salt glucose peptone solution after incubation are divisible into three main classes, namely, (1) those which ferment the medium to the formation of both acid and gas; (2) those which produce acid, but no gas; and (3) those which produce neither acid nor gas, but merely a turbidity. Of course, if the contents of the tubes remain clear, it is evident that the micro-organisms present in the added water are incapable of growing in this particular solution; as a matter of fact, this is not infrequently the case with pure waters.

Now, what is the interpretation to be placed upon these various results? We may say, at the outset, that the organisms which merely grow, but fail to produce either acid or gas in this medium, have little significance in the hygienic examination of water, as practically none of them can be said to be of fæcal origin. Interest, therefore, centres chiefly in the first two classes,

as they are, for the most part, organisms of intestinal type, more especially those of class 1—that is, producers of both acid and gas—as these include all the more important organisms found in sewage. Moreover, as those coming under the second class—that is, producers of acid only—are invariably associated with others belonging to class 1, it is rare to find the production of acid only in this medium, the practical deduction being that it is unnecessary to examine a water sample further if, after having been manipulated and incubated as explained, it is found not to contain micro-organisms capable of producing both acid and gas in the bile-salt glucose peptone litmus solution.

The chief micro-organisms likely to be met with in a water sample, and which ferment the bile-salt glucose peptone solution, are given in the following table:—

GROUP I. Producing acid and gas.	GROUP II. Producing acid but no gas.
B. coli communis.	B. typhosus.
,, acidi lactici.	,, dysenteriæ.
,, lactis ærogenes.	,, para-dysenteriæ.
,, proteus.	,, choleræ.
,, paracoli.	,, prodigiosus.
,, paratyphosus.	Streptococci.
,, enteritidis (Gartner).	Staphylococci.
And other members of the intermediate group.	

In addition to the above-named organisms, it must be clearly understood that a certain number of micro-organisms exist in water, often of undoubted purity, which are capable of producing acid in this medium, and occasionally minute quantities of gas. This fact emphasizes the need of recognizing these reactions merely as preliminary steps in the inquiry as to the existence or absence of objectionable or hurtful types of bacteria in any given water sample, and that no hasty conclusions are to be drawn from the production of gas, and still less so from the mere acidification of the medium after inoculation with varying quantities of water. For these reasons it is imperative to continue the investigation before deciding that the water is polluted. This further investigation involves the plating out in gelatine, or upon lactose agar or any other medium suitable for the isolation and differentiation of specific species. We deem it necessary to lay stress upon this warning, as some workers are tempted to regard these preliminary reactions as specific evidence of pollution. They certainly are not that, though in nine cases out of ten the production of acid

and gas in any of the tubes is strong presumptive evidence of the presence of organisms, in the water, which have been derived from sewage or manurial matter.

Assuming, then, that one or more of the bile-salt tubes, after inoculation with the water sample, have shown acid and gas production, it is then necessary to plate out for the exact differentiation of species. This is best done by making a series of gelatine plates from the tube or tubes which have given the reaction after inoculation with the smallest volume of the water sample. The colonies which develop on the plates must then be examined, any suspicious ones fished off on to agar slopes, and from these cultures further subcultures made in the various media, to be mentioned, to establish the identity of the particular micro-organisms isolated. The various organisms liable to be found in water, capable of producing gas in glucose bile-salt solution, and consequently likely to develop on the various plates set from the original water-seeded bile-salt glucose peptone tubes, may be divided into four great groups. In the first are a number of motile organisms of a somewhat unstable biological equilibrium, which liquefy gelatine, produce gas in glucose and sucrose, but not in lactose, curdle milk very slowly, rendering it acid, and commonly produce indol in peptone solutions. These organisms represent the great *proteus* family. In the second group are motile bacteria, producing gas in glucose, lactose, mannite, and occasionally in sucrose. These curdle milk rapidly with no peptonization of the clot; they nearly always produce indol in peptone solution, but do not liquefy gelatine. They grow characteristically in both of Proskauer and Capaldi's media, producing acid in No. 1 and alkali in No. 2. These organisms are the *B. coli communis*, indifferently derived from the alimentary canal of man and animals. In the third group are non-motile bacteria, not liquefying gelatine, which not only curdle and render milk acid, but ferment sugars, other than glucose, somewhat variably. The type of this group is the *B. lactis aerogenes*. In the fourth group we find motile bacteria, fermenting glucose alone of the sugars, not liquefying gelatine and not clotting milk, but rendering it finally alkaline. These organisms are the intermediates of the colon-enteric series, and include such species as the *B. enteritidis* of Gärtner, the various para-colons and the paratyphoids. Indol production is variable with this series, but not infrequent.

It will be apparent from this summary that the liquefaction or non-liquefaction of the gelatine constitutes a broad line of differentiation between the first group and the others; but it must be borne in mind that all the liquefying colonies on a gelatine plate prepared in this way are not necessarily members of the proteus

group, though, as a matter of fact, owing to the bile-salt apparently keeping back or inhibiting the growth of the common water organisms, which are also capable of liquefying gelatine, the greater number will be found to belong to the great proteus family. Members of this group are invariably found in sewage and in dirty waters, especially where surface washings from manured land gains access to a water supply, consequently their presence in great numbers constitutes a suspicious piece of evidence. On the other hand, one occasionally meets with members of this group in undoubtedly clean and safe waters, but in these cases there is usually a complete absence of members of the other three groups; therefore, in attempting to appraise them at their proper hygienic value, one must have regard to all the facts, more particularly taking into consideration their association or non-association with members of the other groups. In the same way, it must not be hastily assumed that all the non-liquefying colonies are necessarily either *B. coli* or *B. lactis aerogenes*, or one of the various paracolons and paratyphoids: the exact determination of species can be made only by careful subculturing in a variety of media, and a critical noting of their morphology and other features. Precisely the same remarks apply to colonies which may develop on gelatine or other plates inoculated from bile-salt glucose solution, in which acid, but no gas, has formed after the addition of some of the water sample. Some of these may liquefy gelatine (*e.g.* the cholera vibrio) and some will not. Each one of the resulting colonies on these plates will need to be judged upon its individual features as manifested by subculture in various media. While no detailed description can be given of all the possible microbial forms which may be met with in the bacteriological examination of water, still the following short statement, regarding the chief varieties which have a dominant significance in this branch of hygienic investigation, may be of use. The composition and mode of preparation of the various media mentioned are detailed in the Appendix.

B. proteus.—A small bacillus with rounded ends, often in pairs or in chains: it is motile, and not spore-bearing; grows at 42° C., but better at 20° C. It stains with Gram's method. The colonies on gelatine plates after twenty-four hours are delicate granular films of irregular shape; in forty-eight hours they begin to liquefy, and appear like punched-out circles. The colonies in the early stage are usually circular; the margin may show a fine bristly formation or spindle-shaped processes tending to run out all over the gelatine. When grown as a gelatine stab culture, the medium is rapidly liquefied in a funnel-shaped manner. In broth, the growth is diffuse, without pellicle; on agar, the growth is not characteristic,

being moist and greyish-white; on potato, it is moist but yellowish. In media containing glucose or sucrose there is production of both acid and gas, but in lactose there is no fermentation. In milk, clotting occurs in about two days with formation of acid, and in peptone solution there is usually production of indol after about five days.

B. lactis ærogenes.—A non-motile rod decolourizing with Gram's stain. On gelatine plates the surface colonies are porcelain white in colour, and more or less circular; the deep colonies are round, granular, and yellowish-brown in tint. On agar, the growth is opaque and porcelain white. In gelatine stab culture, the growth is free along the line of inoculation, with a nail-head expansion on the surface; the gelatine is not liquefied. In milk, there is coagulation usually within forty-eight hours, with marked production of acid. In broth, there is uniform turbidity, and not infrequently some pellicle. When grown in the various sugars, such as glucose, lactose, sucrose, maltose, and in the alcohol mannite, there is marked fermentation with gas production. In peptone and salt solution, there is usually some indol produced by the fifth day, but some strains fail to make indol. Perhaps the most characteristic cultural reaction of this micro-organism is on potato, where it produces a white creamy growth permeated with gas-bubbles. This organism is common in milk, fæces, and dirty water; it is closely allied to the *B. coli communis*, and liable to be mistaken for it unless care be taken.

B. coli communis.—This important micro-organism appears as a very short bacillus, often resembling a coccus. It is usually motile, but occasionally strains are found to be not so. As a rule, it possesses one to five flagella, but owing to their brittleness these are difficult to stain. There is no spore formation. This micro-organism stains readily with ordinary basic dyes, but is decolourized by Gram's method. On gelatine plates, the deep colonies are not unlike those of *B. lactis ærogenes*, being oval or circular in shape and brown in colour. After twenty-four to forty-eight hours, the surface colonies are thin, bluish-grey, transparent expansions with an irregular margin. Those of *B. lactis ærogenes* never show this expansive growth or the crenated margin. The ridges and surface of the *B. coli* colonies almost invariably shows tracings of furrows running from the centre to the periphery, while at times fine wavy lines parallel to the margin are to be seen. These features of the surface gelatine colonies are usually sufficient to differentiate it from the *B. lactis ærogenes*, whose surface colonies are coarser, less expanded, and altogether lacking in that delicate mother-of-pearl-like appearance so characteristic of the common colon bacillus. The gelatine is not liquefied. As a gelatine

stab, there is a nail-head-like surface expansion and marked growth along the line of inoculation. When grown as a streak on a gelatine slope, the growth is white, broad, and marked by a crenated margin. On agar, the growth is not characteristic. In broth, a general turbidity results, but usually no film or pellicle. On potato, the growth commonly takes the form of a thick brownish-yellow layer. Milk is coagulated usually within forty-eight hours after incubation at 37° C. with formation of acidity. Indol production is almost invariable in peptone and salt solution, after five days' incubation at 37° C. When grown in media containing glucose, lactose, maltose, or mannite, there is free production of acid and gas; some few strains of this organism ferment sucrose, but in our experience the typical *B. coli communis* derived from the human intestine does not split cane-sugar. When grown in the two media suggested by Proskauer and Capaldi, there is an acid growth in No. 1 after twenty-four hours' incubation at 37° C., while in No. 2 medium there is a similar growth, but the reaction is either unchanged or rendered faintly alkaline. Some writers have laid stress upon the reaction obtained with *B. coli communis* when grown in glucose-agar coloured with neutral red, when the magenta red is changed to a yellowish-green florescence after two days' incubation at 37° C. In the majority of cases this does occur, but we are indisposed to regard it as in any way specific or characteristic of this particular micro-organism. The foregoing description gives the chief characteristics of the typical *B. coli* as commonly met with in dirty water, in sewage, and from human or animal excrement, but it must be borne in mind that varieties are not uncommon which fail to conform to the type. The chief departures from the type are inability to produce indol and to bring about coagulation of milk within three or four days. We have never come across any of these aberrant forms in dirty water without finding them associated with others which conform strictly to the classic type; it is the association or not with organisms undoubtedly *B. coli communis* which must guide the worker in the formation of an opinion as to whether he has isolated a presumably fæcal organism or not.

The Intermediates.—Under this heading are embraced a number of micro-organisms which, from their cultural reactions, occupy an intermediate position between the typical *B. coli* and the *B. typhosus*. They are motile rods, staining readily with ordinary dyes, decolourizing by Gram's method, not liquefying gelatine, and producing on that medium surface colonies which present many points of resemblance to those of the common colon bacillus. Their characteristic features are an ability to gaseously ferment glucose and maltose, make acid in mannite, failing to clot milk,

but rendering it finally more or less alkaline. They invariably fail to ferment, even to the formation of acid, either lactose or sucrose. Typical members of this group are the various paracoli bacteria, the paratyphoids, the *B. psittacosis*, the *B. icteroides*, the bacillus alleged to be the cause of epidemic jaundice, and the *B. enteritidis* of Gartner, an organism which has been associated with certain forms of diarrhœa and acute infection presumably due to contaminated or degraded meats. The occurrence of members of this group in water samples is, in our experience, rare; but an appreciation of their biological position, and as possible fermenters of bile-salt glucose broth, is necessary on the part of all those who employ this medium in the routine examination of waters.

B. typhosus.—This, the most important representative of the group which produce acid but no gas in bile-salt glucose broth, is a highly motile bacillus without spores, and decolourizing by Gram's stain. It possesses from eight to twelve long wavy flagella disposed all round the bacillus. It grows at 42° C., but better at 37° C.; it fails to do so at 0° C. It is killed by an exposure to 65° C. for ten minutes, and by an exposure of one minute to 80° C. On gelatine plates, the deep colonies are granular, and round or oval in shape. The surface colonies grow slowly, requiring seventy-two hours usually before they show their characteristic appearances as thin bluish-grey films with an irregular margin; under a low power markings are seen which look like ridges and valleys running irregularly from the centre to the periphery—in fact, these colonies resemble closely those of the *B. coli* and some other members of that group. Occasionally the surface colonies of the *B. typhosus* are without the "relief-map" appearance, and merely finely granular resembling a thin film of glass. The gelatine is not liquefied. When stabbed into gelatine, the surface growth is like the plate-surface colonies, and along the line of inoculation there is a fine growth of discrete white points or masses. If streaked on a gelatine slope, a white narrow growth develops along the line of inoculation with an irregular margin, but the whole growth is less marked than the corresponding culture of *B. coli.* The main point of distinction between the respective growths of these two micro-organisms upon gelatine is the relative slowness of development on the part of the enteric organism. On agar, the growth is not characteristic, being moist and grey. On potato, a smooth glistening film forms, which is so devoid of colour and structure as to be very difficult of detection with the naked eye. In broth, there results a diffuse cloudiness, without pellicle. In glucose, maltose, and mannite, the *B. typhosus* produces acid but no gas, while in lactose and sucrose there is not even acid. After a week or more of incubation at 37° C. in peptone and salt solution there is no formation

of indol. Milk, even after a fortnight's incubation at 37° C., is unchanged to the naked eye, but there is invariably the production of some acidity. In the media suggested by Proskauer and Capaldi (see Appendix) the reaction of the *B. typhosus* is typical, namely, after twenty-four hours' incubation at 37° C. no growth in the No. 1, but a marked acid growth in the No. 2. In these reactions it will be seen this micro-organism differs markedly from the common colon bacillus. If some enteric serum is available, valuable evidence as to identity is obtainable by noting its agglutinability or not.

Closely allied to the *B. typhosus* in many of its cultural reactions is the *B. dysenteriæ* and certain associated species. From the examination of a considerable number of *B. dysenteriæ*, we are disposed to lay stress, as a means of diagnosis, upon the facts that the *B. dysenteriæ* is never so motile as the enteric organism; it further never makes acid in mannite, it does not agglutinate with an enteric serum, and, moreover, tends to produce alkalinity in milk on prolonged incubation. In all its other cultural reactions it practically is identical with those described as typical of *B. typhosus*. The various para-dysentery bacilli, or, as we prefer to call them, the *B. typhosi simulantes*, offer many points of resemblance to the enteric organism, and as they are not infrequently isolated from waters, their due discrimination is important. Judging by our own experience, these micro-organisms differ from the true *B. typhosus* only in that they fail to agglutinate with enteric sera; they are at best but feebly motile, usually produce indol, and render milk faintly alkaline. On the other hand, they stand apart from the *B. dysenteriæ*, in that they are non-pathogenic to rabbits and guinea-pigs, are not readily agglutinated with dysenteric sera, produce acid in mannite and indol in peptone and salt solution.

Apart from these, there are many organisms which present superficial resemblances to the *B. coli communis* and the *B. typhosus*, and whose isolation from water samples may give rise to difficulties. The more common are the atypical members of the coli group, reference to which has been made already. The *B. acidi lactici* produces surface colonies somewhat like those of the enteric and colon bacilli; but it is a spore-bearing organism, coagulating milk, producing indol, and forming gas in glucose media. Another micro-organism which may give trouble is the *B. ureæ*, and occasionally found in dirty water. Its surface colonies on gelatine are of the colon-enteric type, but it does not react to either typhoid or dysenteric sera, and rapidly converts urea into ammonium carbonate. The *B. sulcatus* is a common water organism which occasionally is mistaken for both *B. coli*

and *B. typhosus* on gelatine plates in their early stage. It can usually be recognized by the fact that the colonies acquire a yellow colour. Their subcultures are readily distinguished by the facts of not coagulating milk, producing no indol, and forming no gas in glucose. Similar difficulties may arise with another common water organism, namely, the *B. fluorescens non-liquefaciens*, but its fluorescence is characteristic, it produces no gas in the various sugars, and does not coagulate milk. The possible presence of this and other similar micro-organisms in a series of plates set from a water culture should be borne in mind: in no case should an opinion as to identity be formed hastily or from an examination of a mere surface or other colony; each suggestive colony must be fished off on to an agar slope, and the final judgment found only upon a critical analysis of the subcultural reactions in various media.

The **Spirillum choleræ** is an important organism to those engaged in examining water supplies in tropical countries. It is a small curved micro-organism resembling a comma, usually only one curve is seen, but sometimes two spirilla are attached ends on, and an S-shape produced. It is very motile, having a single flagellum at one end. It does not form spores, but degraded or involution forms are not uncommon, when it appears short and thick like a large coccus. It is markedly ærobic, and grows best at 37° C. The colonies on gelatine plates, in twenty-four to forty-eight hours, appear as minute white points, which under a low power show an irregular margin. Later liquefaction of the gelatine occurs. If grown as a gelatine stab, well marked liquefaction is seen on third day as a funnel-like depression. The growth on an agar slope is not characteristic, but on agar plates the surface colonies appear under a low power as very transparent brownish-yellow circular discs. In broth there is diffuse turbidity with a thin pellicle on the surface. Milk remains unchanged; the growth on potato is not characteristic. Indol and nitrite production is rapid and marked in peptone and salt solution, requiring only the addition of a few drops of pure sulphuric acid to show the so-called "cholera red" reaction. There is no production of gas in the sugar media, but acid is formed in glucose. If a cholera serum is available, agglutination of this spirillum is marked in dilutions from 1–10 to 1–120.

The difficulties of diagnosing the true cholera spirilla in water are often great, and mainly owing to the fact that large numbers of other spirilla may be present which are not necessarily pathogenic. The following is the simplest and most practicable method for the isolation of the cholera spirillum from a water sample. It is based upon the fact that the optimum medium for the growth of the organism is one containing 1 per cent. of peptone and 0·5 per cent. of salt, and really consists in converting as much of

the suspected water as possible into such a solution, incubating at 37° C. for a few hours, and if the spirilla are present isolating them from it. The technique suggested is to make a strong or stock solution containing 10 per cent. of peptone and 5 per cent. of salt; add 10 c.c. of this solution to 90 c.c. of the water sample in a sterile flask, and then incubate for from fourteen to twenty hours at 37° C. If cholera spirilla are present they will be found in the scum or pellicle which forms on the surface of the water. Loopfuls from this surface water should be removed and plated out in gelatine or smeared over the surface of solidified agar in a series of Petri dishes. These must then be incubated for another twenty-four hours, and carefully examined for colonies of the suspected spirillum; any suggestive colonies must be subcultured and judged by their resulting reactions.

Streptococci.—The hygienic significance to be attached to the presence of these micro-organisms in water has been much debated. They undoubtedly are present in large numbers in all sewage, and can be found, too, if searched for, in the majority of polluted waters. Owing to their minuteness, the delicacy of their colonies, and the not infrequently large volumes of water which must be concentrated for their detection, the routine search for these micro-organisms is the exception rather than the rule in the bacterial examination of water samples. We are disposed to think that this neglect of noting the presence or absence of streptococci is unwise, as although the presence of streptococci alone cannot be considered as indicating necessarily a dangerous contamination, still, in view of the fact that these organisms tend to rapidly disappear in dilutions of old sewage, their presence in a water supply indicates a recent contamination, but unless they are accompanied by the presence of *B. coli* this contamination is not necessarily dangerous. On the other hand, their absence does not of itself imply purity and safety; while their presence, at all events in any number, even in the absence of *B. coli* and other fæcal organisms, is evidence highly suggestive of doubt as to the fitness of a given sample for domestic use, and should be a signal for a more critical inquiry into the circumstances.

The streptococci are small or medium-sized cocci arranged in chains of varying length. They stain with the basic dyes and also by Gram's method. The greater number of strains which we have isolated from sewage and sewage-polluted waters do not liquefy gelatine, but a few varieties do so. On gelatine plates, the surface colonies are granular, circular, and extremely small, with a clear sharp edge, but a few present streaming projections from the margin. In broth, the resulting growth is generally diffuse. Milk is clotted usually by the third day. In peptone

and salt solution indôl is produced. Glucose and lactose media are acidified, but there is no gas formation. On potato and on agar, the growths are not characteristic. In bile-salt glucose broth, there is usually a definite production of acid without gas. Although these are the cultural features of the greater number of strains which have come under notice, it must be borne in mind that certain varieties do not conform absolutely to these reactions, the more notable exceptions being an ability to liquefy gelatine and a tendency to form clumps like staphylococci rather than chains. For the isolation of streptococci from water, the concentration of not less than 500 c.c. to 10 c.c. by filtration through a sterile bougie, and subsequent plating in gelatine or on agar, probably constitutes the most satisfactory technique.

Parietti's Method.

This is based upon the fact that many fæcal organisms, notably the *B. coli* and the *B. typhosus*, will grow freely in a broth containing from 0·05 to 0·15 per cent. of phenol, whilst the growth of the greater number of water organisms is inhibited. A stock solution, containing 5 grms. of pure carbolic acid and 4 grms. of hydrochloric acid in 100 c.c. of distilled water, is made. Of this solution, 0·1, 0·2, and 0·3 c.c. are added to a series of tubes each containing 10 c.c. of ordinary broth, so that the tubes contain 0·05, 0·1, and 0·15 per cent. of phenol. Varying small quantities of the water sample, say 1 c.c., are then added to twenty or more of such phenolated broth-tubes, and then incubated at 37° C. for twenty-four hours. If the water is suspected of containing comparatively few organisms, it may be advantageous to concentrate by passing one or two litres through a sterile bougie filter, diffusing the deposit brushed from the filter surface into 10 c.c. of sterile water, and then adding 1 c.c. of this to each of the phenol broth-tubes. Polluted or doubtful waters when mixed with phenol broth, and incubated for twenty-four hours at 37° C., produce a visible and uniform turbidity, whilst pure waters treated in the same way produce no change, or at most a turbidity which is not uniform. Assuming this procedure to have been adopted with a sample, all the tubes which show a uniform turbidity should be plated out in gelatine, or streaked upon agar plates, and the colonies resulting after incubation examined, isolated, and duly subcultured in the various media for identification. Both in this and MacConkey's method, it is often convenient to streak plates of litmus tinted lactose agar (see Appendix) with small quantities of the growths from the various broth-tubes. This is an excellent method for rapidly differentiating the coli organisms from some others, such as

the enteric and dysentery micro-organisms, the former producing red-tinted colonies by production of acid from the lactose, while the latter two give blue colonies owing to their having no action on the sugar. Useful as Parietti's method is, we think it of less practical value than MacConkey's, mainly because it deals with but a relatively smaller quantity of the water sample, and is, moreover, more tedious and more liable to error.

The Significance and Detection of the B. Enteritidis Sporogenes of Klein.

Since Klein first described this micro-organism as being found in all sewages, dirty waters, horse-dung, and earth from manured fields, its presence in or absence from water samples has been deemed a matter of importance. It is an obligatory anærobic bacillus of considerable size, of variable mobility, staining by Gram's method, and producing under certain conditions oval spores situated in the middle of the rods. On solidified serum it grows well at 37° C., the serum being gradually liquefied, and spores forming about the third day. It grows well also in glucose agar, splitting and tearing up the medium by a copious formation of gas-bubbles. It grows in much the same way in glucose gelatine, slowly liquefying the gelatine. On the surface of an agar slope, the colonies are grey, flat expansions, having no crenations, and the individual bacilli producing no spores. When grown in milk, there is a rapid separation of acid whey and flocculi of casein, much gas formation with a distinct smell of butyric acid. No spores are produced in milk. The separated whey swarms with the bacilli, and is actively virulent if injected into rodents.

The hygienic significance to be attached to this micro-organism has been much debated. Our experience indicates it to be invariably present in horse-dung, street-sweepings, manure from fields, and in most sewages. Its detection in undoubtedly dirty and sewage-polluted waters is not constant, so much so that we are disposed to doubt whether its importance, as an indicator of sewage in water samples, has not been overrated. Many of the discrepancies as to this micro-organism appear to be due to the fact that there are two other organisms in constant association with filth and decomposing animal matter which present marked resemblances to the *B. enteritidis sporogenes* of Klein, and with which it seems to have been confused; these are the *B. butyricus* of Botkin and the *B. cadaveris sporogenes*. The following table (given by Klein) shows the essential difference between these three anærobic bacilli:—

B. enteritidis sporogenes.	B. butyricus.	B. cadaveris sporogenes.
Broad cylindrical rods, staining with Gram; some motile.	Same as *B. enteritidis sporogenes*.	Cylindrical, thin, thread-like rods; very motile; staining with Gram.
Oval spores situated in the middle of rods.	Same as *B. enteritidis sporogenes*.	Oval spores situated at end of the rods, drumstick like.
Grows well on gelatine, which it slowly liquefies.	Does not liquefy gelatine, but grows as a mass of convoluted threads.	Liquefies gelatine rapidly, emitting a putrid odour. Free spore formation.
As a stab in gelatine, spherical colonies appear with no filamentous projections. Slow liquefaction.	As a stab in gelatine, spherical colonies with horizontal filamentous projections. No liquefaction.	As a stab in gelatine, rapid liquefaction with putrid odour.
On an agar surface, gives circular flat colonies. No spore formation.	On an agar surface, grey flat colonies with crenated edge. No spores.	On an agar surface, thready, branched colonies, rapidly forming spores.
As a stab in agar, little tendency to form lateral branching. Much gas, no spores.	As a stab in agar, characteristic bundles of threads project laterally in the depth. Much gas, no spores.	As a stab in agar, free growth of threads along the stab. Much gas, rapid spore formation.
In milk there is a rapid separation of acid whey and flocculi of casein. Much gas, no spores, but marked smell of butyric acid.	Same as *B. enteritidis sporogenes*.	In milk, much gas formed, also rapid spore formation; the milk is slowly decomposed.
On serum, free growth with slow liquefaction. Spores are formed.	On serum, grows well, very slow softening.	On serum, rapid liquefaction, with putrid odour and free spore formation.
Injected into rodents. Very virulent.	Not pathogenic to rodents.	Not pathogenic to rodents.

Experience indicates that, unless care is exercised, it is easy to confuse these micro-organisms one with the other, especially if too much reliance is placed upon the milk reaction. Unless an organism gives all the reactions, particularly that of pathogenicity, it should not be called the *B. enteritidis sporogenes*, but for practical purposes of water analysis it appears sufficient to identify any one of these three anærobic bacilli, as the presence of any one of them is significant of pollution. As these spore-bearing organisms occur rarely in large numbers in even dirty waters, the bacterial contents of a fairly large volume of the water sample should be used for their detection. This should be about 500 c.c., which must be filtered through a sterile bougie, the organisms arrested

on the surface of the filter being then brushed by means of a sterile brush into 10 c.c. of sterile water. Varying proportions of this must be then transferred to tubes of recently boiled sterile milk, the temperature of which at time of inoculation should not exceed 80° C., and then grown anærobically. The portions may be conveniently distributed into three milk tubes, namely, 6 c.c. into one, and the remaining 4 c.c. equally into two others. Some melted vaseline is then poured over the surface of the milk, in order to exclude air by formation of a covering some half inch in depth. The milk tubes are then placed in a water-bath at 80° C. for twenty minutes, cooled until the vaseline is well set, and finally incubated at 37° C. for three days. If any of these anærobic bacilli are present, the typical changes in the milk tubes will be produced. If no result is produced in any of the three tubes inoculated, the water sample may be said to contain less than one spore per 500 c.c.; if the typical change occur in the one which received the 6 c.c. of filter brushing, but not in the other two, the water is assumed to contain less than one spore per 100 c.c., but one or more in 300 c.c. If the typical change occurs in one or both the other tubes, there is probably one or more spores in each 100 c.c. of the sample. If the milk reaction is so atypical as to raise doubts as to whether the organism present is really the *B. enteritidis sporogenes*, but rather one of its allies, the point can only be settled by careful subculture on the lines indicated. We have never detected any of these anærobic micro-organisms in a water sample, without finding concurrent evidence of the *B. coli* and other fæcal forms.

The Interpretation of the Results of a Water Analysis.—This often offers undoubted difficulties, especially to the student and others depending exclusively upon the results of a chemical analysis. The reasons for this are twofold: (1) at best the indications given by the chemical examination are only relative, as the results obtained cannot be interpreted correctly except by reference to local standards; (2) between an undoubtedly good water and an undoubtedly dirty water there is a considerable range of waters whose chemical analytical features are very ambiguous. There is no general standard which can be fixed for all waters; the source and its immediate surroundings must be known before a reliable opinion as to the quality of the water can be given. What we need is a carefully constructed series of water standards for individual areas or districts. These standards should relate not only to chemical constituents but to bacterial contents. These standards would be of great value in respect of surface waters, where any serious departure from the average would at once suggest cause for critical inquiry as to the why and wherefore. In

the absence, then, of district standards or averages, what can be done? We can depend only upon the following procedures, which we place in their order of value: (1) a careful local inspection for any source of possible pollution; (2) a bacteriological examination made as soon as possible after collection of the sample; (3) a chemical analysis. It is rare for a sample of water to yield doubtful results under either the second or third heads when the report under the first has been carefully obtained and found to be free from suggestive features. We, therefore, attach the greatest importance to this matter of local inspection, feeling sure that if carefully and intelligently carried out it affords information of the greatest value. In the preceding pages an attempt has been made to show on what lines a bacterial examination of a water sample should be conducted, and the probable results likely to be obtained in the case of clean and dirty waters respectively. We are indisposed to lay down numerical standards as to the presence of individual bacterial forms in waters: such we know have been formulated, but, in our opinion, they are apt to be used in too routine a manner. Each individual water sample must be judged on its merits with due regard to all the facts. While it is difficult to conceive a properly constructed deep well, and apparently remote from sewage pollution, yielding a water containing any fæcal micro-organisms, no matter how large a volume were carefully examined, it involves less imagination to account for the presence of such forms in comparatively small amounts of surface water, such as are obtained from lakes, ponds, rivers, or shallow wells imperfectly protected. As to the chemical results, we would say no more than that the evidence of present or recent animal pollution is especially suggested by high chlorine and oxidized nitrogen in association with marked free and albuminoid ammonia; that of past or remote animal pollution by high chlorine and oxidized nitrogen (not explicable as derived from geological strata) with generally little free and albuminoid ammonia. If the fouling is chiefly of vegetable origin, we may expect to find high figures for albuminoid ammonia and oxygen absorbed in association with low figures of chlorine and oxidized salts of nitrogen. Beyond this general statement we are not prepared to dogmatize; it may be asked, what constitutes a high figure in respect of these various constituents? The line of demarcation in each case may be taken for practical purposes at the figures already given when explaining the respective analytical procedures advocated.

As typical of actual analytical results, a few examples of waters from different sources, with expressions of opinion upon them, are given in the following table:—

ANALYSIS OF WATERS, EXPRESSED IN PARTS PER 100,000.

Source and circumstances.	Chlorine.	Nitric and nitrous nitrogen.	Nitrites.	Free ammonia.	Albuminoid ammonia	Oxygen absorbed	Bacteriological results	Opinion.
1. Shallow well, risk of sewage from blocked drain suspected	12·5	1·5	traces	0·005	0·006	0·15	B. coli found	Unsafe.
2. Spring, close to a ditch liable to overflow	4·0	1·7	nil	nil	0·006	0·20	Sewage organisms present	Unsafe.
3. Deep well, coping, cover, and steining defective	29·0	0·11	nil	0·055	0·002	0·11	Sewage organisms present	Polluted and unsafe.
4. Deep well, well protected	2·8	0·03	nil	0·010	0·004	0·06	No sewage forms present	Safe.
5. Shallow well, apparently well protected	2·2	0·002	nil	0·011	0·009	0·2	No sewage forms found	Doubtful; unsatisfactory.
6. Surface water from moor, well policed	1·0	0·16	nil	0·003	0·012	0·290	No sewage forms found	Safe.
7. Spring, well protected	3·0	0·6	nil	0·009	0·006	0·122	No sewage forms found	Safe.
8. Deep well in farmyard	19·0	0·39	traces	0·018	0·004	0·110	Sewage forms found	Unsafe; polluted.
9. Shallow well in farmyard	1·0	0·8	nil	nil	0·003	0·040	No sewage forms found	Safe.
10. Spring in pasture field, not well guarded; ditch near, liable to overflow	3·9	0·2	nil	0·008	0·03	0·180	Sewage organisms found	Unsafe and polluted.
11. Deep well, protected	22·0	0·09	nil	0·011	0·004	0·060	No sewage forms found	Safe.
12. Spring in a copse, no protection	1·6	1·1	nil	0·02	0·001	0·015	No sewage forms found	Unsafe.

CHAPTER III.

FOOD.

The Classification, Nature, and Uses of Food Stuffs.—We may define the word *food* as including everything we take into our bodies which either directly or indirectly goes to the growth and repair of the body or to the production of energy or functional activity in any form. This definition necessarily includes not only all the ordinary articles consumed in eating and drinking, but also water and air. Since, however, the taking in of air into our lungs is mainly an involuntary act, it is customary not to include air and its constituents taken into our bodies by the lungs as foods, but to strictly limit the term *food* to substances taken by the mouth into the digestive tract.

It is convenient to speak of the various substances which constitute food as *proximate principles*, because, consisting as they do of carbon, hydrogen, oxygen, and nitrogen, combined more or less into highly complex bodies, they really are elementary constituents or proximate principles of the human organism. These elementary or proximate principles may be conveniently classified as follows:—

- Organic.
  - Nitrogenous, such as the proteids or albuminous bodies.
  - Non-nitrogenous
    - Fats or hydrocarbons.
    - Starches, sugars, or carbohydrates.
    - Vegetable acids.
- Inorganic. Mineral salts.

Both these great classes are present in all ordinary articles of diet, no matter whether they be derived from animals or vegetables. In the case of man's food, we must add to the above a third group, which includes the so-called "food accessories," such as tea, coffee, alcohol, etc.

It must be noted that the simplest division of the organic constituents of food is into the nitrogenous and the non-nitrogenous, or those which contain nitrogen and those which do not. Now, the proteids alone contain nitrogen. Just as the greater part of the air is made up of nitrogen, so is the greater part of our body (bone excepted) made up of proteid, or nitrogen containing substances. A large amount of nitrogen in the form of urea, uric acid, and other substances, is daily being lost from our bodies by the urine; and to repair this loss, a daily intake of nitrogenous food is required. The only form of nitrogen food which the body can make use of is that of proteid or albuminoids. A plant

equally needs nitrogen, but this it obtains from the ammonia and nitrates of the soil, which are much simpler bodies than proteids.

All **proteids** are composed of carbon, hydrogen, oxygen, nitrogen, and sulphur, with occasionally a little phosphorus. Their general percentage composition may be taken as being: nitrogen, 16 parts; carbon, 54 parts; oxygen, 22 parts; hydrogen, 7 parts; and sulphur, 1 part. The proteids, when regarded as foods, are divisible into two great groups, according to their nutritive value. The more nutritious one is the group of true proteids, consisting of albumin, myosin, glutin, casein, legumin, and peptones; in them, the proportion of nitrogen to carbon is nearly as 2 is to 7. The other, or less nutritious, group is sometimes called the albuminoid group; its members include substances obtained only from animals, such as gelatin, chondrin, ossein, and keratin; in them, the proportion of nitrogen to carbon is as 2 is to $5\frac{1}{2}$.

Albumin constitutes the essential constituent of that substance which, called by physiologists protoplasm, really is the physical basis of life. In its most familiar form, we find it as egg albumin, or that which makes up nearly the whole of the white and a third of the yolk of an egg. A similar body is serum albumin, or the chief solid constituent of blood serum.

Myosin, or muscle albumin, is present largely in muscle, from which it can be obtained by first washing out all the serum, then dissolving the mass in a 10-per-cent. solution of common salt, and dropping the semi-solid substance into a vessel containing distilled water, in which it forms a flocculent deposit.

Glutin is an insoluble proteid obtained from the seeds of most of the cereals. If a little flour be placed in a piece of muslin and a stream of water be allowed to run on it, as the water leaves the paste it will be quite milky, and if collected, the white powder which makes it milky will settle at the bottom of the vessel. The powder thus obtained from the flour is starch. The substance which remains in the muslin is not at all like flour or dough, but is a sticky substance, and is really nearly pure glutin.

The three foregoing substances have one common feature, namely, that they are coagulated by heat; and when so coagulated, as in cooking, they are not dissolved by either water or dilute acids and alkalies, but are readily dissolved and digested by the gastric juice of the stomach.

Casein is the nitrogenous solid present in milk, familiar to us all as the curd which forms when an acid is added to milk.

Legumin is a proteid very much resembling casein, but present chiefly in the seeds of beans and peas.

Peptones and *albumoses* are forms of proteids very closely

related one to another, and though probably widely distributed in vegetables and plants, are chiefly formed by the action of pepsin upon ordinary proteids. The albumoses are, strictly speaking, precursors or bodies formed before peptones during digestion of proteids. The peptones are remarkable for their extreme diffusibility and ready absorption by the alimentary canal. Owing to their easiness of digestion, these forms of proteid are now largely given in the various kinds of partly artificially digested foods for the sick, though it must be remembered that they do not possess the same nutritive value as the ordinary proteids of food. Both casein and the peptones have the common characteristic of not being coagulated by heat.

As closely allied to the foregoing may be mentioned *syntonin*, or acid albumin, which exists in some meats, and also *alkali albumin*. These are formed by the action of dilute acids and alkalies on the ordinary proteids, and are not precipitated from solutions by boiling.

The albuminoids, such as gelatin, chondrin, etc., are bodies closely resembling the albumins, but probably not existing as such in the tissues of the body, but only obtained from them by prolonged boiling. These bodies are easily dissolved in hot water, and yield more or less the same products after digestion as the proteids, but appear, on the whole, to have a less nutritive value than them. Gelatin is obtained by boiling bones and cartilage. Experiments go to show that life cannot be sustained when this is the only nitrogenous matter taken as food; although, if used alone, it appears to have only small nutritive value, still, if other proteids be taken with it, it has some value. Glue of all kinds is really a form of impure gelatin obtained by boiling the horns and hoofs of animals.

From what physiology teaches us, we know that the cells which go to make up the animal body are formed of "protoplasm," and that consists of the proteids taken in as food; so that, to all intents and purposes, the nutrition of the nitrogen containing tissues means the nutrition of the body. As to the precise part played by the proteids of our food in the nutrition and work of the body, considerable misconception existed until within comparatively recent times. This was mainly due to the teaching of Liebig, who, assuming that each organ in the exercise of its function consumed a certain proportion of its own substance, and that muscle being essentially a nitrogenous tissue, maintained that our need of proteid food was in a direct ratio to the amount of muscular activity exhibited. If this were the case, then the elimination of urea and uric acid, which together practically represent all the nitrogenous matter changed in the body, should be

proportional to the amount of work done; but such is not the case. On the contrary, as shown by Voit, the greater or less amount of nitrogen got rid of by the kidneys depends, not upon the amount of muscular work done, but really upon the quantity of nitrogen taken in as proteid food; so that the main part of the proteid substances taken in as food is, at least for a time, stored up in the body generally, to be used up as required by the tissues for their repair and growth, and, in a limited sense, also as a source of some of the fat of the body and of the glycogen found in the muscles and liver; any excess over these needs being at once metabolized and eliminated. From this it is evident that the proper supply of the proteid food stuffs is of the first importance, though an excess of proteid food throws an excess of work on the nitrogenous tissues. The natural law seems to be that to preserve health the nitrogen taken must equal that destroyed.

Fats or Hydrocarbons.—These are compounds of glycerine with the fatty acids, oleic, stearic, and palmitic acid, etc. They all contain carbon, hydrogen, and oxygen, but no nitrogen, and may be represented by the general formula $C_{10}H_{18}O$. The proportion of oxygen in them, however, is insufficient to combine with all the hydrogen present so as to form water. When taken as food, the fats not only repair or renew the fatty tissues, but yield energy and heat, owing to their oxidation into carbon dioxide and water. In addition to this, they help in the proper digestion of the other foods, possibly owing to their power or influence in promoting the flow of bile and the pancreatic juice. When consumed as food, the fats are not acted upon by either the saliva in the mouth or by the gastric juice of the stomach, but reach the small intestine more or less unchanged, where they become emulsified by the bile and pancreatic juice, and in the emulsified state are readily absorbed by the lacteal vessels. Fats are found in the majority of diets of all nations, and by those living in very cold countries, the amount consumed is very large. When hard work is being performed, an increase of fatty food is demanded.

Carbohydrates.—This is a large group, and embraces all the various starches and sugar, also cellulose and gum. Like the fats, these contain no nitrogen, but only carbon, hydrogen, and oxygen; these two latter elements exist in sufficient proportion to form water, hence their name, "carbohydrates." In the main, the carbohydrates are derived from the vegetable world, though lactose, a kind of sugar, is found in milk, and glycogen, a form of starch, exists in the liver.

The *starches* constitute a large class of foods, and, existing in

the form of granules, constitute the chief portion of the seeds of the various cereals and potatoes. Starch combines with iodine to form a blue colour, constituting thereby a simple test for its presence. In cold water or alcohol, starch is insoluble, but at about 180° F. water causes the granules to burst and swell out. Heat and dilute acids convert starch into a gum-like substance, called dextrine, and, if carried further, into grape sugar. A similar action is produced upon starch by the saliva and pancreatic juice. Starch, represented by the formula $C_6H_{10}O_5$ under the influence of these juices, takes up an atom of water H_2O and becomes $C_6H_{12}O_6$, or grape sugar; this, on being taken up by the blood, is carried along the portal vein to the liver, where it is deposited as glycogen or liver starch, to be subsequently supplied to the system as the needs of the body demand. When exposed to the action of diastase, which is a peculiar ferment existing in all germinating seeds during growth (malted barley, for example), starch is converted into another form of sugar called maltose, $C_{12}H_{22}O_{11}$, H_2O, a substance isomeric with lactose.

The sugars belong practically to one or other of two kinds, namely, the sucrose or cane-sugar variety, and the glucose or grape sugars.

Cane sugar, or *sucrose*, is the ordinary sugar of commerce, extracted chiefly from sugar cane. It is a crystalline body, not soluble in either absolute alcohol or ether, though freely so in weak alcohol; in water, its solution is thick and syrupy. Cane sugar is represented by the formula $C_{12}H_{22}O_{11}$, and to its group belong *maltose* and *lactose*. The former is a low form of sugar, the final product of the action of diastase on starch. Lactose, $C_{12}H_{24}O_{12}$, or sugar of milk, is a variety of sugar found only in the milk of the mammalia. It is only partially soluble in either hot or cold water, and not directly susceptible of alcoholic fermentation except under the action of weak acids which convert it into grape sugar. In the presence of any decomposing proteids, lactose is transformed into lactic acid. One of the most remarkable features connected with the sugars is their power of deflecting a ray of polarized light to either the right or left. Cane sugar has a specific rotating power of 73°·8 to the right; maltose has a similar power of 155° to the right; while lactose has an action on polarized light in the same direction of 61°·5.

Grape sugar, or *glucose*, also called dextrose, or starch sugar, exists ready formed in grapes and other fruits, but is also made on a large scale from starches either by treating them with dilute acids or by the action of malt; in fact, grape sugar is the first product during the fermentation of either cane sugar, milk sugar, or starch, and is represented by the formula $C_6H_{12}O_6$. When a solution of

cane sugar is boiled with dilute mineral acids, the sugar is split up into two glucoses, thus—

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

One of these rotates polarized light to the right, hence called dextrose; the other rotates it to the left, hence called levulose. This mixture of dextrose and levulose is often called invert sugar, because the polarization of light is the opposite of that of cane sugar, for although dextrose or glucose rotates to the right some 57°·6, and levulose to the left, yet the latter rotates so much more, namely, 108°·8, that the combined solution polarizes distinctly to the left. Glucose or dextrose is soluble in both water and dilute alcohol, and is directly broken up or fermented by yeast into alcohol and carbon dioxide; thus—

$$\underset{\text{Grape sugar.}}{C_6H_{12}O_6} = \underset{\text{2 Alcohol.}}{2(C_2H_6O)} + \underset{\text{2 Carbon dioxide.}}{2(CO_2)}$$

Among carbohydrates must be included cellulose and pectose. *Cellulose* constitutes the chief framework of plants; it is quite insoluble, and without any dietetic value. In a similar way, *Pectose*, or vegetable jelly, is found in various ripe fruits, being really a later stage of the insoluble body present in most unripe fruits, and known as pectin. Its precise composition is unknown.

In their physiological use, the carbohydrates closely resemble the fats or hydrocarbons; being directly used in contributing to the maintenance of animal heat and the production of force or energy as well as the formation of fat. They, however, differ from the fats in that the amount of them consumed as food is proportional to the quantity of CO_2 excreted; with fats this is not so. Performing as they do in the body similar functions, it has been surmised that fats and carbohydrates might be mutually interchangeable as articles of diet. On this point, although the evidence is not very precise, the general consensus of opinion is that they are not wholly interchangeable, though perhaps practically so, as instanced by the fact that, owing to their relative cheapness, carbohydrates largely replace, but not completely, the fats in the diets of the poor. A certain degree of health can be maintained on a diet of proteids, fats, salts, and water, but the absolute withdrawal of fats and a bare substitution of carbohydrates for them rapidly leads to a loss of vigour and health. The truth probably lies in the acceptance of an admixture of both fats and carbohydrates in the diet.

Vegetable Acids.—These, though not strictly speaking foods, play so important a part in preserving the health of man that they demand some considerable notice. The chief among them are

tartaric, citric, malic, oxalic, and acetic acids. *Tartaric acid*, $C_4H_6O_6$, exists largely in grape juice chiefly as the acid tartrate of potassium; *Citric acid*, $C_6H_8O_7$, is found in oranges, lemons, and gooseberries; *Malic acid*, $C_4H_6O_5$, is met with in fruits belonging to the rose order, such as apples and pears; *Oxalic acid*, $C_2H_2O_4$, is present largely in rhubarb and sorrel; *Acetic acid*, $C_2H_4O_2$, constitutes the active element in vinegar. Except it be the latter, all these vegetable acids contain more than sufficient oxygen to convert all their hydrogen into water. These acids exist mainly in fresh fruits and vegetables, either as free acids or in combination with alkalies as alkaline salts, and, when taken into the body, form carbonates, which exercise a controlling influence in preserving the alkalinity not only of the blood but other fluids; they also furnish a small amount of energy and heat by oxidation. Their absence for any length of time from any dietary leads to a peculiar lowering or weakening of the blood, resulting in the disease called scurvy. It is possible that some of these acids are not only derived from fruits and vegetables, but also in a small degree from the splitting up of carbohydrates, so that even the latter, in an indirect way, help in maintaining the alkalinity of the blood and other animal fluids.

Mineral Salts.—Among the mineral salts which constitute a part of the proximate principles of food must be included chloride of sodium or common salt, the phosphates of lime, potash, soda, and magnesium, along with small quantities of sulphates, and possibly iron. These, in their various and respective ways, are essential for the repair and growth of all parts of the body. The uses of the chlorides, as typified by common salt, are very important. The complete withholding of ordinary salt from food leads to rapid disease, and even death. The chlorides generally keep in solution the globulins of the blood and other fluids, while at the same time are the source of the hydrochloric acid of the gastric juice, and materially aid in the solution of albumin. The phosphates of lime, potash, and magnesia contribute, especially in the young, to the formation of bone; while iron forms an important part of the hæmoglobin of the red blood corpuscles.

If we remember that 64 per cent. of the body consists of *water*, the need of it is not difficult to understand. Though a portion of it is obtained by the oxidation of the hydrogen in the tissues, still the greater part is derived from that taken in as food. In the body itself, water serves chiefly for the solution and conveyance of food to different parts of the system, for the excretion of effete products, for the equalization of heat by evaporation, both from the lungs and skin, as well as for the regulation of all the chemical and mechanical functions of the body.

The Nutritive Value of the Food Stuffs.—In the preceding pages we have learnt the part which the various food stuffs play when taken into the body; it is now necessary to learn their nutritive value. To begin with, if we lift a weight by our hands, muscular force is employed in the act, and the energy evolved in this or any other muscular action must have its origin or source in something. As a matter of fact, the energy so evolved has its source in the material which has been supplied to the body in the form of food. Every process of our bodies, no matter whether it be the moving of a hand or a foot, the beating of our heart, or the secretion of saliva, is attended with some manifestation of energy, and this energy is shown in one or other of two forms, namely, either mechanical labour or heat. These facts will be more clearly understood if it is borne in mind that what is called *energy* in an agent is merely an expression that that agent is capable of doing work, and that the quantity of energy it possesses is measured by the amount of work it can do. An agent or force is said to do work when it produces any change in the condition of bodies; therefore energy is the capacity for producing physical change. This capacity for producing change or energy is of two kinds, namely, *kinetic energy* or the energy of movement, and *potential energy* or that of position. This latter term means various forms of energy, which are suspended in their action, and which, although they may cause motion, are not in themselves motion. Thus, a coiled watch-spring possesses energy of position or potential energy, and only wants a touch to transform the energy of position into energy of movement, or potential into mechanical energy. Moreover, this transformation of potential energy into kinetic, or *vice versâ*, can take place without any part of the energy being lost, and it is further possible to convert the whole of the energy possessed by any body into heat. Thus if a piece of lead be thrown from a high tower to the ground, and if it strike some hard, unyielding substance, the movement of the lead mass is not only arrested, but its kinetic energy is transformed into violent vibratory movements of the lead atoms. As a result of this violent vibration of atoms, heat is produced, and the amount of this is proportional to the kinetic energy of the lead, which again was proportional to its potential energy when in position on the tower. In the human body the ordinary movements of the whole system and of individual organs are constantly being transformed into heat. If we regard, therefore, the food we consume as the direct source of all this heat and the mechanical energy displayed by the body, it is obvious we can obtain by their measurement a fair idea of the nutritive values of various

food stuffs. The problem is, however, not of a uniformly simple nature. In the case of the water and mineral salts of the food, their nutritive value is not difficult to ascertain, because they are simple bodies, and do not undergo any very great chemical change in the body. The nutritive value of the proteids, fats, and carbohydrates, however, is not so easy to determine, because not only are they complex bodies in themselves, but, moreover, undergo complicated and ill-understood changes within the body; their nutritive value, therefore, cannot be very accurately expressed.

The simplest measure of the potential energy is the amount of heat which can be obtained by complete combustion of the chemical compounds representing the potential energy. The various statements as to the amount of potential energy possessed by various food stuffs, and expressed either in terms of heat or work, are based upon the researches and discoveries of Mayer and Joule, that the amount of power or energy which can be obtained from a given weight of matter is connected with and proportional to the heat given out during its combustion. As a standard of measure of heat, we have the "heat unit," or *caloric.* This heat unit, or calorie, is the amount of energy required to raise the temperature of 1 kilog. (or 1 litre) of water 1° C., or, which is the same thing, 1 lb. of water 4° F. This heat unit corresponds to 425,500 units of work, which are grammetres; or a weight of 425·5 kilogs., if allowed to fall from a height of 1 metre, would by its concussion produce as much heat as would raise the temperature of 1 litre of water 1° C. In other words, one calorie, as a measure of the work derivable from a food stuff, is equal to 425·5 kilogrammetres.

According to the English system the heat unit is the amount of energy required to raise the temperature of a pound of water 1° F., and will, if manifested as a mechanical force, raise 772 lbs. a foot high, or, what amounts to the same thing, 1 lb. 772 feet high. Thus the dynamic or mechanical equivalent of one degree of heat on the Fahrenheit scale is said to be 772 foot-pounds. Adopting the Centigrade scale, then the mechanical equivalent of 1° C, or 1°·8 F., will be 1389 foot-pounds; that is, the energy which will raise the temperature of 1 lb. of water 1° C., or 1°·8 F., will be capable, as a motive power, of raising 1 lb. in weight 1389 feet high. In England the amount of work done is commonly expressed as foot-tons or tons lifted 1 foot; while in France it is often expressed as kilogrammetres or kilogrammes lifted 1 metre.

Units of work, expressed according to the continental system as gramme-metres, can be converted into foot-pounds by multiplying them by 0·007233, and into foot-tons by dividing by 311,000. Similarly, kilogrammetres are converted into foot-pounds by

multiplying by 7·233, and into foot-tons by dividing by 311; also calories into foot-tons by multiplying by 1·36.

Applying this principle, that as heat production is related to the amount of chemical action ensuing, so likewise is mechanical power production, we find that as a measure of the utility of food, the value of the various food principles as mechanical power producers will correspond with their value as heat producers. Those food principles, which by oxidation give rise to the greatest amount of heat, will, of course, theoretically have the greatest capacity for the production of working power; that is, will possess the greatest potential energy. This theoretical potential energy is not only different in the case of each class of food stuff, such as proteid, fat, and carbohydrate, but differs also in different foods of each of these classes. In the case of many food stuffs, their actual value in respect of capacity for heat production has been determined experimentally, and expressed in relation to the performance of work.

The following table gives the number of calories yielded by the complete combustion of 1 grm. ($15\frac{1}{2}$ grs.) of some common foods:—

Arrowroot	3·90	Eggs	1·60
Bacon	8·86	Gelatin	3·00
Beef (fat)	3·27	Glutin	3·92
Beef (lean)	0·98	Macaroni	3·40
Biscuit	3·10	Milk	0·75
Bread (coarse)	3·00	Oatmeal	3·60
Bread (fine)	2·75	Peas	3·31
Butter	8·60	Potatoes	0·98
Cabbage	0·34	Rice	3·50
Carrots	0·57	Sugar (cane)	3·34
Cheese	2·40	Sugar (grape)	3·27

The above figures refer, of course, to laboratory experiments, involving a complete combustion of the food stuff, but in the body it is practically only the fats and carbohydrates which are completely burnt; while the proteids are not metabolized beyond the stage of urea, which we know escapes in the urine. Rubner has shown that, if allowance is made for such incompletely oxidized products, the heat value of 1 grm. of the chief alimentary principles, when taken into the body, is as follows:—

	Calories.
Proteid	4·1
Fat	9·3
Carbohydrates	4·1

If we know what is the percentage composition of any given food in terms of proteid, fat, and carbohydrates, it is quite easy to find the total calories yielded by 100 parts of the food in

question. Where the amount of food is expressed in ounces, the above statements must be multiplied by 28·34, as there are rather more than $28\frac{1}{3}$ grms. in an ounce; in other words, an ounce of proteid or carbohydrate would yield 116 calories, while an ounce of fat would yield 263·5 calories.

From what has been said, it is evident that it is difficult to compare rightly the potential energy available by the burning of a food stuff outside the body with that which is obtained as the result of combustion within the body, and in attempting to estimate the nutritive values therefrom, allowance must be made for the different degrees of digestibility, the effects of cooking, and even the actual bulk taken. In the case of fats, their nutritive value seems to depend largely on their digestibility, while of the carbohydrates there is little reason to think that starch, grape sugar, or cane sugar differ much in their nutritive value, though Lawes and Gilbert's experiments indicate that cane sugar is more fattening than starch. Among the proteids, we know that gelatine and chondrin have a lower nutritive value than the ordinary proteids, and that vegetable proteids are as nourishing as the animal.

With regard to mechanical or useful labour and the amount of energy expended by the body, it is considered that 300 foot-tons or 226 calories of external work over and above what is done by the functional activity of the body itself is a good day's work. The internal or functional work of the body is generally placed at 2000 calories, or say 2800 foot-tons. Over and above this functional work, one-fifth roughly of available energy from food is capable of being turned into useful work—that is, we must supply as food sufficient energy to meet the internal needs of the body *plus* five times the energy required to be demonstrated as external work. On this basis the following may be accepted as standards of the number of calories which must be supplied for work of different degrees of severity:—

	Calories.
1. Rest (clerk working in an office)	2500
2. Professional work (lawyer or doctor)	2650
3. Moderate muscular work	3100
4. Severe muscular work	3600
5. Hard work (navvy)	5000

Diets.—So far, we have discussed the nature, uses, and nutritive values of the food stuffs individually; it is necessary now to briefly discuss them collectively in reference to their powers of maintaining life—whether any one of them alone is capable of supporting vitality, or what combinations and what quantity of them experience and experiment teach us are useful in the food of man. There is abundant evidence to prove that no one

group of alimentary substances is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from instinctive proclivities, from considerations of the comparative anatomy of our digestive organs, from experience and experiment. That man cannot live on any one group of the food stuffs is shown by an examination of the needs of the body, as demonstrated by the daily loss by the kidneys, bowels, skin, and lungs.

Various experiments by Parkes, Smith, Playfair, Haughton, Fick, and Ranke have shown that an average man gives off 307 grs. of nitrogen and 4700 grs. of carbon daily. If he wishes to keep in health, this daily loss of nitrogen and carbon must be made up by a corresponding intake of those elements with his food. If such a man subsisted only on a carbohydrate food stuff—say, for instance, bread, which contains 116 grs. of carbon and 5·5 grs. of nitrogen in each ounce—he would, in order to obtain the 307 grs. of nitrogen needed by him, have to consume 3·1 lbs. of bread, while at the same time the necessary quantity of carbon is contained in 2·5 lbs. Or, to take the suppositittous case of a man wishing to live on beef (representing the proteids), and having a composition of 60 grs. of carbon and 10·3 grs. of nitrogen in each ounce, he would, in order to obtain his 4700 grs. of carbon, have to eat daily no less than 4·7 lbs. of that substance, while the required 307 grs. of nitrogen are contained in 1·3 lbs. Therefore, to obtain the proper quantity of carbon, he would be consuming a quantity of meat which contains nearly four times the amount of nitrogen actually required.

The general principles of diet may be summed up in the words of de Chaumont: (1) No single nutritive principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a long time, but for a permanency salts would require to be added. Thus proteids and fats, or proteids and starches, would support life. (3) For the best forms of diet, both fats and carbohydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar among them. It would also appear that a due admixture of more than one form of nitrogenous principle is advisable.

Experience teaches us that our requirements as to food vary much with our exposure to different conditions, and that according to the expenditure of our bodies so should the materials be supplied which are best calculated to yield what is wanted. The human body has been compared to a machine, but it differs therefrom in this, that wear is constantly going on independently

of any useful work done, which is not the case in a mechanical engine. Determinations as to the quantity of food daily required by the body have been obtained by means of extended observations of the diets of classes and communities, and also by estimating the sum of excreted matters, which, of course, must be compensated by a suitable supply of food.

The following table (modified from Atwater) gives the composition of the ordinary diet actually consumed by individuals of diverse nationality and different social rank :—

Classes	Nutritive constituents				Potential energy.
	Proteid	Fat.	Carbo-hydrate.	Total	
	Grammes.	Grammes.	Grammes.	Grammes.	Calories.
Sewing girl (London)	53	33	316	402	1820
Factory girl (Leipzig)	52	53	301	406	1940
Labourer (Lombardy)	82	40	362	484	2192
Student (Japan)	97	16	438	551	2343
Lawyer (Munich)	131	95	327	553	2700
Master tailor (England)	131	39	525	695	3053
Blacksmith (England)	176	71	667	914	4117
Workman (Russian)	132	80	583	795	3675
Glass-blower (American)	95	132	481	708	3590
Artisan (Canada)	109	109	527	749	3622
Brickmaker (American)	222	260	758	1243	6460
Weaver (Lancashire)	114	150	522	786	4000

The experiments of Parkes and Pettenkofer upon men to a great extent confirm the conclusions as to the daily needs of man as drawn from a study of class diets. The amounts of carbon and nitrogen taken daily in food are of the highest importance, since these are the chief elements which undergo metabolism in the body. The following table shows the quantity of carbon, nitrogen, etc., in each ounce of the various dried food stuffs: –

One ounce (dried)	Nitrogen.	Carbon.	Hydrogen.	Sulphur.
	Grains.	Grains.	Grains.	Grains.
Proteids	70	212	8	6
Fat	-	336	48	—
Carbohydrates—				
1. Starch	-	194	—	—
2. Cane sugar		184	-	-
3. Grape sugar	—	175	—	—
4. Milk sugar	—	175	—	—

The total carbon in an ounce of proteid is 233 grs., but of this 30 grs. are only metabolized as far as urea, and oxidized as carbon monoxide; making allowance for this, we have a nett total equal to 212 grs. of carbon fully oxidized from each ounce of dry proteid.

Assuming these compositions in terms of nitrogen and carbon of the various food stuffs, and accepting that the daily need of an average adult man to keep in health is equal to 307 grs. of nitrogen and 4700 grs. of carbon, certain *standard diets* have been compiled. Adopting an average of the statements of various authorities, the following amounts express the standard diet for an adult weighing 150 lbs., in terms of dry or water-free food stuffs:—

Kind of work.	Proteid.	Fat.	Carbo-hydrate.	Potential energy.
	Grammes.	Grammes	Grammes	Calories
Ordinary work . . .	121	59	510	3135
Hard work	161	98	520	3706

These amounts are, of course, theoretical standards, and, as such, only approximate. The need of so great an increase in the proteids during hard work is doubtful, while, on the other hand, the need of carbon under the same conditions is possibly greater than given in the above table. As already stated, all the ingredients are reckoned as being quite free from water, but would in actual practice be combined with quite their own weight of water, making the total weight of solid food taken to be from 40 to 20 ounces. In addition, too, some 60 to 80 fluid ounces of water would be taken as drink. As a general rule, it may be accepted that a man consumes daily about $\frac{1}{100}$ of his own weight of dry food, and some $\frac{3}{100}$ of water, or, in other words, each pound of his body weight receives in twenty-four hours 0·15 oz. dry food and 0·5 oz. of water.

It will be readily understood that, though the above-named amounts are accepted as standards, in actual life there are very great individual differences in diets, and that no single standard will meet all cases, because no two men eat exactly the same. The chief influences which affect the amount of food and drink taken are sex, age, work, and climate.

As regards *sex*, women are said to require 10 per cent. less than men; while in reference to *age*, during young life nitrogenous and fatty food are particularly needful to provide for the growth of tissues; in old age, proportionate reductions are demanded, as

there is not only lessened labour but actually lessened body metabolism or tissue change. If people are doing great *work*, there is a natural need of more food, especially for proteids and fats; also in a less degree for water. The influence of *climate* on diet is not very defined. In cold countries more fat is consumed than in hot, but how far this increase is due to greater need for energy and body warmth or increased exertion is not quite clear.

In all good and well-considered diets there is a definite proportion between the nitrogenous and non-nitrogenous food stuffs—usually in the ratio of 1 to 3½ or 4½; and the nitrogen should be to the carbon as 1 is to 15. The ratio between fats and carbohydrates which should be aimed at in all diets is roughly as 1 is to 9, but for economical reasons the proportion varies constantly in different practical dietaries.

Having, therefore, an established series of dietetic standards and a knowledge of the chief points to which attention must be directed in regard to food, it is important to be able to examine any given diet in the light of these facts, and be able as well to construct a dietary. To do this, however, it is necessary to have some knowledge of the mean composition of the various articles of diet. The table, constructed from various sources, shows the percentage composition of the more ordinary articles of food.

	In 100 parts—				
	Water	Proteids	Fats.	Carbo hydrates.	Salts
Arrowroot	15·40	0·80	—	83·5	0·30
Bacon (Letheby)	15·00	9·00	73·00	—	3·00
Barley meal (de Chaumont)	11·30	12·70	2·00	71·00	3·00
Barley pearl (Church)	14·70	7·40	1·10	75·80	1·00
Beef, best quality (Konig)	72·00	21·00	6·00	—	1·00
Beef as supplied to army	75·00	15·00	8·40	—	1·60
Beef, salted	49·10	29·60	0·20	—	21·10
Beef, corned or Chicago (Parkes)	52·20	23·30	14·00	—	4·00
Beetroot (König)	87·00	1·50	—	10·50	1·00
Biscuits	8·00	15·60	1·30	73·40	1·70
Bread (Rubner)	39·50	8·00	1·00	50·00	1·50
Bread, average wheaten	40·00	8·00	1·50	49·20	1·30
Butter, English fresh (Bell)	12·00	2·00	85·00	—	1·00
Butter, very best (Bell)	8·00	1·00	90·00	—	1·00
Butter, salt (Bell)	17·00	—	80·00	—	3·00
Butter, highly salted (Bell)	17·00	1·00	74·00	—	8·00
Cabbage (König)	89·00	2·00	2·00	5·50	1·50
Cabbage, Brussels sprouts	85·50	5·00	0·50	7·80	1·20
Carrots (Konig)	87·80	1·00	0·20	10·00	1·00

	In 100 parts—				
	Water.	Proteids	Fats.	Carbo hydrates	Salts.
Cheese, Dutch (Bell)	41·00	28·00	23·00	1·00	7·00
Cheese, Single Gloster	36·00	31·00	28·50	—	4·50
Cheese, poor quality (Bell)	48·00	32·00	9·00	7·00	4·00
Cream (Letheby)	66·00	2·70	26·70	2·80	1·80
Eel (Konig)	57·50	12·50	28·50	—	1·50
Eggs	73·50	13·50	11·60	—	1·40
Fish, salmon (Konig)	76·00	15·00	7·00	—	2·00
Fish, sole (Konig)	86·00	12·00	0·50	—	1·50
Fish, herrings fresh (Konig)	80·00	10·00	8·00	—	2·00
Flour, wheaten fine	16·50	13·00	1·50	68·30	0·70
Flour, wheaten average	15·00	11·00	2·00	71·20	0·80
Goose (Konig)	38·00	16·00	45·50	-	0·50
Horse-flesh (Konig)	74·30	21·70	2·60	—	1·00
Lentils	12·50	24·80	1·80	58·40	2·50
Macaroni (Konig)	13·10	9·00	0·30	76·80	0·80
Maize (Pozziali)	13·50	10·00	6·70	64·50	1·40
Margarine	12·03	0·75	82·00	—	5·22
Milk, average cows	86·90	4·70	3·50	4·20	0·70
Milk, Devon preserved (Blyth)	90·35	4·20	1·15	3·50	0·70
Milk, average town	86·00	5·00	4·00	4·30	0·70
Milk, condensed English (Bell)	27·00	12·00	8·40	50·80	2·00
Milk, condensed Swiss, sweetened	25·60	12·30	11·00	48·70	2·40
Milk, condensed Swiss, unsweetened	61·85	11·35	11·25	13·35	2·00
Mutton, ordinary	76·00	18·00	5·00	—	1·00
Oatmeal	15·00	13·00	6·00	63·00	3·00
Parsnips (Parkes)	82·50	1·30	0·70	14·50	1·00
Peas	15·60	22·00	2·00	58·00	2·40
Pork (Konig)	47·50	16·00	34·00	—	2·50
Potatoes	74·00	2·00	0·20	21·84	1·00
Rice	10·00	5·00	0·10	84·40	0·50
Turnips (Konig)	91·00	1·00	0·20	6·80	1·00
Veal, lean (Konig)	78·00	19·00	1·50	—	1·50

Calculation of Diets.—Of course these figures are merely approximate; but are sufficiently accurate for the calculation of any dietary, the mode of doing which is sufficiently simple as shown by the following example. How much proteid, fat, carbohydrate, and salts are contained in 12 ozs. of average wheaten bread? On referring to the table, we find that every 100 parts of bread contain 40 of water, 8 of proteid, 1·5 of fat, 49·2 of carbohydrate, and 1·3 of salts. By a simple rule of three sum, we find that the 12 ozs. contain 4·8 ozs. of water, 0·96 oz. of proteid, 0·18 oz. of fat, 5·9 ozs. of carbohydrate, and 0·15 oz. of salts.

It is the great diversity which exists as regards the food

consumed by the human race in all parts of the world that is the most remarkable feature in the study of dietaries. Some people live upon a wholly vegetable, others on a wholly animal, and others on a mixed diet. It has already been explained how unsuited any single vegetable food, such as bread, or any single animal food, such as meat, is to supply the daily requirements of the body, and how a judicious mingling of the various food stuffs affords the greatest nourishment in the least bulk. The mixed diet may be regarded as that which in Nature's plan is designed for man's sustenance. On this he appears to attain the highest intellectual and physical vigour, and it is this diet which he consumes by general inclination when circumstances allow the inclination to guide him; also it is in conformity with the construction of his teeth and the arrangements of his digestive apparatus in general. However, where custom and habit have given certain races a peculiar suitability for a purely vegetable diet, the arguments in favour of a mixed diet are not sufficiently strong for the reversal of the customs of many ages.

For translating or changing the elements of a diet into terms of food articles, or *vice versâ*, it is important to remember that no mere calculation of the amounts of food stuffs can properly measure the efficiency of any particular diet, but that other conditions must be considered; the chief of these will be relative to hours and arrangements of meals, digestibility of food, and the effects of cooking.

Hours of Eating.—Next to the quantity and quality of food, attention must be given to the method of taking it. Food should be taken with regularity and at proper periods; long intervals between meals are specially hurtful. As a rule, it may be said that the hours of eating meals are the result of custom and of the other trivial conditions peculiar to different classes of society. The prevailing custom is for these meals to be taken during the day at intervals of about five or six hours. Observation has shown that an ordinary meal is digested and has passed on from the stomach in about four hours' time, and thus, according to the above custom, the stomach is allowed to remain for a short period in a state of rest before it is filled with food again. Whether the largest meal of the day, dinner, should be taken at midday or at sundown is a question mainly to be decided by circumstances. The former hour is found to be more convenient to men doing manual labour, while the latter seems to be best adapted to the wants of the busy man in the upper and middle classes. Provided the evening meal is not taken at too late an hour, and not too large, there is no reason against this arrangement; but it must not be forgotten that the habit of going to bed or to sleep

on a full stomach after a meal is particularly injurious. Similarly, a hearty meal should neither follow nor precede violent exertion. In each case, the stomach is unfit for the vigorous discharge of its office. All persons, both rich and poor, should endeavour to take a little food with either a cup of hot tea or coffee in the early morning before going out to work. Such a practice strengthens the body and digestion at a time when its powers are at their lowest, and, too, in malarial countries has a marked influence in keeping off fever.

Digestibility of Food.—Far more important, as an index of its nutritive value, than mere calculations as to how much proteid, fat, etc., a given article of food contains, is the determination of the degree of its digestibility. On this point it may be said that the proteids and fat derived from the animal world are more readily digested than those obtained from vegetables. As to the carbohydrates, no general rule can be laid down beyond that white bread and rice are the most digestible. The following table shows the coefficients of digestibility of the different groups of foods, expressed as percentages :—

	Proteids.	Fats.	Carbohydrates.
Animal food	98	97	100
Cereals and sugars . . .	85	90	98
Vegetables and fruits . .	80	90	95

These figures must, however, be regarded only as giving broad differences of digestibility between foods, and in particular cases may be considerably modified, especially if allowance be made for the effects of cooking.

Cooking.—By cooking, our food is rendered more pleasing to the eye, agreeable to the palate, and digestible by the stomach. Apart from its power of removing any obnoxious property in a food by killing any parasites or disease germs existing in it, cooking so alters the texture of a food as to render it more easy of mastication and subsequent reduction to a fluid state by the stomach. Thus a piece of meat before cooking is tough and stringy, but when cooked the muscular fibres are given a firmness from the coagulation of their albumin, and the connective tissue which binds the muscle-fibres together is made into a soft and jelly-like mass. The result of all this is, the meat is rendered less coherent and more digestible, and capable of being broken down by the teeth and the digestive juices. In the same way, cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices to penetrate into their substance. It also aids digestion by its action of breaking up the starch granules, which exist so largely in vegetables and grains; if not so broken up, starch offers considerable resistance to

digestive action. The warmth imparted to food further aids digestion, and exerts a reviving effect on the system.

We may say that there are six common methods of cooking; namely, boiling, stewing, roasting, broiling or grilling, baking, and frying.

Boiling.—This may have for its object either the extraction from the food of its nutritive principles or their retention in it. If we wish to extract all the goodness of meat into some surrounding liquid such as water, as when we make a soup or a broth, the article should be finely cut up and placed in cold water. After it has soaked for some while, heat should be applied slowly; if a broth is to be made, the heat, though constantly applied, is not allowed to reach actual boiling for some time, by which procedure much of the albumin of the meat is extracted before the subsequent greater heat has been able to coagulate it, and, all the natural juices having for the most part flowed out, the meat itself is left in a nearly tasteless state, but not without some nutritive value. In the making of a soup the same procedure is adopted, with this difference, however, that the boiling is kept up somewhat longer, whereby more of the gelatin of the meat is extracted, and the actual meat itself, owing to more complete deprivation of its constituent juices, rendered still more tasteless and less nutritious. Thus treated, the meat yields its essential principles to the surrounding liquid, which gains in flavour and nutritive properties, the essential difference between the broth and the soup being merely one of degree—that is, how much of the goodness of the meat passes out of it into the surrounding liquid. In the making of a broth some of the meat juices, gelatin, and other constituents still remain in the meat, because the albumin is permitted to coagulate before they have all escaped; while in the other case practically nothing remains of the meat but fibrous tissue, all the rest having passed out into the soup. A due appreciation of the difference between a broth and a soup is important, especially the fact that after the making of a broth the meat residue has still considerable nutritive value, whereas after the preparation of a soup the meat residue has none.

If, on the other hand, the object of boiling is not to extract the constituents out of meat, but rather to retain in it all its flavour and nutriment, then it should not be cut up, but left as a large piece, plunged suddenly into hot or nearly boiling water, and quickly brought to the boil. The application of sudden heat in this manner coagulates the albuminous matter on the surface of the meat, closes its pores, makes an impermeable external coat which stops the escape of the juices from the inner and deeper parts. It is on this principle that a boiled leg of mutton is

cooked, taking care, in order to complete the cooking, that the boiling is neither too vigorous nor too long continued, but, after the first short period of boil, the water is only just allowed to simmer—that is, be barely at the actual boil. If cooked carefully in this way, the central part of such a joint remains juicy and tender. The most usual fault of cooking meat in this manner is allowing the water in which it is boiled to remain at too high a temperature after the first dipping in to coagulate the surface. The actual period of boiling need not and should not last longer than a few minutes; after that the temperature required for the surrounding water is not greater than 160° F., actual boiling being 212°. It is usual to add salt to the water in boiling a joint such as has been just explained. There are certain reasons for so doing: first, it has a direct coagulating effect upon the surface albumin; second, it slightly raises the boiling-point of water; and third, it increases the density of the water, the effect of which is to render less active the oozing out of the meat juices.

The same principles should guide us in boiling a fish, but with this reservation—namely, that fish being relatively fragile as compared with red meat, many kinds would break if suddenly dipped into boiling water. To avoid this, water just below the boiling-point must be used, and the whole process of cooking the fish be completed without actually boiling the water at all. The breaking of a fish by the agitation of boiling water not only spoils the look of the fish, but also opens up the flesh, producing outlets for the escape of its juices, and thereby losing some of its nutritive elements, besides spoiling its flavour. One of the most prevalent errors amongst unscientific cooks is the idea that by boiling is meant vigorous bubbling of the water: more good is done, and just as much heat obtained, by a very gentle simmer of the water as there is when the saucepan lid is constantly being lifted. The cooking-point of meat is a temperature of 160° F., while the boiling-point of water is 212° F. The same principle of trying to retain the soluble and diffusible constituents of a food is involved when potatoes are boiled in their skins; but in the case of a vegetable like the potato, we retain its constituents within it, not by coagulating any surface albumin, because there is none, but by boiling them in their skins or jackets. Over 50 per cent. of the saline constituents of the potato is potash, and potash is an important constituent of blood, hence the great importance of not allowing any waste of the potash from the potato by allowing it to be largely dissolved out of it during the act of cooking by boiling after peeling. It will readily be seen that this loss of potatoes does not occur when potatoes are cooked in such a manner as to be eaten with their own juice (broth) as in Irish stew, in

which case their previous peeling does no harm. Steamed potatoes possibly lose less potash juice than when boiled. Speaking generally, boiled food is less tasty, but more digestible than when cooked in any other way.

It will be convenient here to discuss another cooking method, namely, *stewing*, because it is commonly regarded as a mere modification of boiling; this is only partially true, because they are essentially opposite processes. If the reader has understood what has been written above upon the boiling of a leg of mutton, he will see that its object is to so raise the temperature of the meat, using water as the medium by which the heat is conveyed to the meat, that it shall as nearly as possible retain all its juices. Now, in stewing, this is largely reversed, because the water is used not only as a heat-giver, but also as a solvent for extracting from the meat more or less of its juices. Much of this extraction of meat juice in stewing is more accurately expressed as an act of diffusion rather than of solution, capable of being best secured at high temperatures than low; but experiment teaches us that albumin, which so largely constitutes the diffusible juice of meat, coagulates and gets hard and tough if long exposed to a heat anything near the boiling-point of water; hence the need, if stewing is to be properly done, and the meat not rendered so tough, curled, and hard as to be more or less uneatable, that the process of stewing should be performed at a temperature of 160° F. or so. This can be readily done if a *bain-marie*, or water bath, be used. The ordinary carpenter's glue-pot is a familiar form of water bath, being simply a vessel immersed in an outer vessel of water. The water in the outer vessel may boil, but that in the inner one never does, because evaporation from its surface keeps its temperature lower than that of the water from which it gets its heat. All well-equipped kitchens have these double vessels, and every ironmonger sells them; but in the absence of such a double saucepan, every housewife can readily improvise one by performing the stewing in an earthenware jar or glass placed within an ordinary saucepan containing water. It is the more general appreciation of the value and use of the water-bath mode of stewing by French men and women that makes their average cooking so much higher than that of the average English man or woman. English people are apt to speak with contempt of the stewed beef of the Frenchman, forgetting the fact that he never eats it alone, but always associated with a soup or *potage*, which really contains the juices of the beef; and the two dishes combined constitute identical and quite as nutritious articles of diet as the British joint.

Hashing is the same process as stewing, only that the meat has been previously cooked instead of being fresh.

Before dismissing this subject of stewing, a few remarks upon the making of ordinary beef-tea or beef extracts as sold under the names of "extract of meat" and "Bovril" may not be inappropriate, particularly as they afford some points of difference from the juices of an ordinary stew. Beef-tea is made by chopping up lean meat very finely and then macerating it in cold water, and the broth thus obtained heated in order to alter its raw flavour. During this heating, which should not exceed 160° F., or just sufficient to coagulate the albumin and colouring matter, a sort of scum rises to the surface; much of this is fat, and is rightly removed, but if the heating is carried too high, some of the other nutritious elements coagulate on the surface, and get removed instead of being left behind. If well prepared, beef-tea is a highly nutritive and restorative liquid, with an agreeable, rich, meaty flavour. If badly prepared, by being subjected to prolonged boiling, beef-tea is merely a solution of the non-coagulable saline constituents of meat—namely, bodies known as kreatin, kreatinin, lactic acid, and phosphates. These are all most excellent, but to be regarded as stimulants rather than as nutrients. This explains why in some states of prostration, during illness, when the blood is insufficiently supplied with these flesh juices, the administration of beef-tea, beef extracts, and such-like preparations does much good; but the danger lies in their being regarded as foods suitable for the normal sustenance of the body. This they are not, and, from the very nature of their composition, wanting largely of the nutritious constituents of meat, they never can be.

Roasting.—Just as stewing may be regarded as the national method of cooking on the Continent, so may roasting be regarded as our national method of flesh cooking. Roast meat is usually thought to be more savoury but less digestible than when either boiled or stewed, while, too, the loss is greater, but the same principle underlies it, namely, the retention of the nutritive juices by the formation of a coagulated layer on the surface. In roasting, the juices of the meat are retained (with the exception of those which escape as gravy on the dish), while in stewing, they go more or less completely into the water. In stewing, the heat is communicated to the meat by convection or actual contact; in roasting, the heat is nearly all dry heat radiated to the surface of the joint from the fire. The high temperature rapidly given by radiation to the meat surface forms a thin crust of hardened and half-carbonized albumin; this prevents the evaporation of the meat moisture, sets up a certain amount of pressure inside the joint resulting in the gradual loosening of the fibres and raising of the deeper parts of the flesh to the cooking temperature

of about 160° F. In all roasting processes, to hasten its course and prevent burning of the superficial parts, the joint is *basted* or kept constantly enveloped in a varnish of hot melted fat, which, while assisting in the communication of heat, checks the undue evaporation of the juices, or, in other words, during roasting heat convection is established by the medium of a fat bath, while in stewing or boiling it is supplied by a water bath. This mode of cooking in a fat bath is applicable not only to ordinary joints but to fish, which, in the form of fillets of plaice or skate, supplemented by roasting in bacon fat and garnished with some previously well-boiled haricots, constitute both a savoury, cheap, and nutritious meal for any poor man.

Broiling or *grilling* is the same in principle as roasting, but the scorching of the surface is greater owing to the larger surface exposed to heat. Baking is analogous, except that the operation is carried on in a confined space, such as an oven. Owing to the confined space and want of ventilation in the chamber or oven in which baking is carried on, the condensed vapour from the article being cooked and the fatty acids, if it be meat, are prevented from escaping, rendering the food so cooked richer and stronger for the stomach. For these reasons, baked food is unsuitable for the sick and delicate.

Frying, speaking generally, is a bad way of cooking, as owing to the heat being applied through the medium of fat, the article so cooked is penetrated with oily matter and often indigestible. In frying, the heat is applied usually much above that of boiling water, as the medium fat can be heated much above 212° F. before it boils; and it is probably largely the difference of temperature to which fish is subjected in the two processes that causes the difference between a boiled sole or mackerel and a fried one. Over and above this, their difference may be due to the fact that the flavouring juices are retained in the flesh of the fried fish, while more or less of them escape into the water when boiled.

It is needless, perhaps, to say that all things used in cooking should be scrupulously clean and carefully cleansed with boiling water after each time of use.

Diseases attributable to Faulty Dieting.—That evils may arise from the indigestibility and bad cooking of food has already been alluded to. There remain for consideration certain bad effects which may arise from either defects as to quantity or quality. The alterations in quantity of food may be either in the direction of excess or deficiency. *An excess of food*, due to too large or too frequent meals, usually leads to an accumulation in the bowels resulting in dyspepsia, constipation, or even irritative diarrhœa. The excess of food may in some cases be absorbed, but more

usually large quantities pass away by the bowel absolutely undigested. Any excessive consumption of proteids, especially if unaccompanied by a proportionate increase of exercise, usually results in enlargement of the liver with more or less dyspepsia, diarrhœa, or even gout, the urine containing an excess of urea, uric acid, and even albumin. An excessive consumption of proteids, with a proportionate reduction of fats and carbohydrates, was the basis of so-called "Banting;" it being an attempt to reduce accumulation of fat in the body by virtue of the well-recognized power which proteids have of favouring a rapid disintegration of tissue. Though physiologically sound, banting is unsuited for indiscriminate use as a means to reduce corpulency. An excess of fats or carbohydrates tends to produce stoutness more or less associated with acidity and flatulency, and if continued long, to degenerative changes in the muscles.

In infants and very young children, an excess of starch or other farinaceous food is conducive to the establishment of the disease known as "rickets."

But little is known of the effects of any excess of mineral salts. Common salt taken in excess increases the change of proteid in the body; while an excess of potash salts in the food leads to an increased excretion of sodium chloride. An excess of water with the food means more urine passed, and also increased tissue activity.

Deficiency of food, if protracted, means, of course, a wasting of the tissues as shown by loss of flesh, poorness of blood, followed by physical and mental weakness, and if the loss reach 40 per cent. of the normal weight of the body—death. The more or less complete deprivation of proteids gradually leads to loss of muscular strength, mental debility, fever, and eventually a degree of prostration which may end in loss of life. A deficiency of fats, even if carbohydrates be given, invariably leads to a lowered state of health. A deficiency or even complete withdrawal of carbohydrates can be borne a long time if fats be given but a deprivation or deficiency of both fats and carbohydrates although proteids are supplied, soon leads to illness. A deficiency of proteids and fats, especially the latter, is the chief characteristic of the dietaries of communities, notably of armies, public institutions, and the poorer classes in general. Any marked diminution in the amount of water taken as food leads to deficient tissue activity, giving rise to undue retention or storage of water in the body, especially in the muscles, with the establishment of defective health and disease-resisting power.

Associated with defects in the supply of mineral salts are two

important diseased states known as rickets and scurvy. Up to within recent years, a view was very generally held that the peculiar disease of childhood known as rickets, characterized by irregular and imperfect ossification of the bones, was due to a deficiency of lime, phosphates, and other salts in the food. In the present day, the real cause is usually regarded as being rather due to the giving of starchy food in excess to infants and children at a time of life when their organs cannot digest it. In scurvy, which is a disease formerly very prevalent in the Royal Navy and mercantile marine, the essential feature is a profound change in the blood, the result being not only effusions of blood into the tissues, but also a condition of great anæmia and prostration. There is much evidence to show that the change of blood in scurvy is really a lessened degree of alkalinity due to the deficiency in the food of the neutral salts of the organic acids, such as citric, tartaric, malic, lactic, and acetic acids. These salts are peculiarly capable by their oxidation in the blood to form alkaline carbonates, with power to preserve the alkalinity of the blood. Thus citric acid and citrate of potash, which are the principal constituents of lime juice and other preventives of scurvy, are oxidized into carbon dioxide and alkaline carbonates of potassium. In a similar way, fresh meat may be antiscorbutic because it contains an appreciable quantity of sarcolactic acid. In this connection, there is a remarkable mass of evidence accumulating which throws doubt upon the acceptance of the older theory that the scorbutic defect in a dietary consists essentially in a lack of vegetable food. It is well known that many outbreaks of scurvy have broken out among expeditions which were well equipped with vegetable food. The dominant factor which we find invariably associated with outbreaks of scurvy is the prolonged consumption of preserved animal food. In our experience, such food undergoes in course of prolonged keeping autolytic changes of a fermentative or analogous nature, in consequence of which the neutral organic salts are changed, and possibly toxic products formed; and it is the ingestion of these substances which affects the alkalinity of the blood and gives rise to scurvy. These deleterious bodies are not due to putrefactive or bacterial decomposition, nor do they reveal themselves by any change obvious to naked eye inspection. They may be well summed up in the term "devitalized food;" this devitalization or material departure from the fresh condition may be the result equally of faulty preservation, caused by exposure to undue heat, as to prolonged keeping: in other words, the more the constituents of a dietary depart from the fresh condition, and the more prolonged the period over which the consumption of such

devitalized food extends, the greater are the probabilities of a development of scorbutic symptoms among the consumers.

The evils or diseased states which are the result of defects in the quality of food are not only many, but so diverse that it will be more convenient to discuss them under the headings of the different articles of food which immediately follow.

Meat.—Although in different parts of the world, the flesh of various kinds of animals is eaten as meat, that chiefly used is beef from the ox, veal from the calf, mutton from the sheep or goat, and pork from the pig. To these may be added the flesh of fishes. As an article of diet, meat furnishes proteids, fat, and salts. A general analysis of meat yields roughly in a hundred parts 75 of water, 20 of proteid, and 5 of fat. The proteid is for the most part myosin, which exists in the muscle fibres. This myosin is, strictly speaking, a globulin, soluble only in saline solutions or dilute acids and alkalies. It is the result of the coagulation of the muscle after death, this coagulation constituting the so-called *rigor mortis*; in this state meat is tough, but when the *rigor mortis* has passed off, the meat becomes tender. The coagulation of the myosin is due to the presence of sarcolactic acid. Besides myosin, meat contains other proteids such as small quantities of alkali and serum albumin, also a globulin from blood. Of the total proteids in ordinary meat some 13 per cent. are made use of in the body, and possibly even more in the best samples. The amount of fat in meat of course varies; it usually solidifies after death, and in bacon consists chiefly of oleates, in beef of palmitates, in mutton of stearates—these respective kinds of fats being soft and fusible in the order named. It is from these animal fats that margarine is made. In good ox flesh about 33 per cent. is fat, in pigs about 50 per cent., in calves about 16 per cent.; in thin or badly fed animals, the fat may be as low as 1 per cent. of the meat.

The mineral salts of meat are chiefly phosphate of potassium with small quantities of magnesium, lime, and chloride of sodium. Besides these, meat yields certain nitrogenous crystalline bodies, called commonly *extractives*. These are derived from the changes in the proteid of muscle, and constitute the stimulating principles of beef-tea and broth. The chief extractives of meat are kreatin, kreatinin, xanthin, taurin, sarkin, and urea. In estimating the dietetic value of meat some allowance must always be made for bone, which, as usually sold, equals at least $\frac{1}{8}$ of the whole, but this is a much less variable item than the fat.

Constituting as it does so large a proportion of the food of man, a proper inspection of meat intended for food is of the first importance, especially with a view to the detection of whether it

be fresh and free from putrefactive changes, and too, whether it be wholesome and sound, and not derived from a diseased animal. It is rare for any one to have opportunities of examining the live stock intended for meat before slaughter. Should such occur it is important to remember that the signs of a healthy animal are, being well nourished, able to rise without difficulty and to walk without lameness. Its coat should be bright and glossy, and free from scabs, boils, or sores. The eyes of the animal should be bright, with mouth and nostrils moist yet free from discharge. The breathing should be quiet and easy, and the breath free from odour.

Inspection of Meat.—Good and healthy butcher's meat is firm and elastic to the touch, moist, but not wet; if well fed, marbled in appearance, from small layers of fat between the muscle fibres. Except in the case of veal and pork, good meat is of a bright red colour. On standing awhile, a red juice oozes out; this should be faintly acid. There should be a fresh but not unpleasant smell. The fat should be firm and whitish yellow in colour, and free from blood-stains. If putrefaction has occurred, the meat is soft, pale, and usually offensive; if a knife or skewer be thrust into such meat and rapidly withdrawn, it will smell offensively. The juice, too, is usually alkaline, and fails to redden blue litmus paper. Occasionally horseflesh is offered for sale in place of beef. Owing to the bones of the horse and ox differing so much one from the other, horseflesh is usually boned before being offered for sale as beef. It is also more oily than beef, and moreover coarser and darker, without the fat layers in the muscle; it has, besides, a characteristic odour. At times, peculiarities of fodder or pasture may give a disagreeable odour to meat, but it is exceptionally rare for any distinct ill effects to result from eating such. Similarly, the meat from animals recently physicked may be less palatable, and is of course proportionately deteriorated in quality. At other times meat may be coarse, tough, and stringy, especially if the animal be aged; such meat should not be regarded as unfit for food simply on account of age. A cow may be slaughtered as late as twenty years of age, though in such a case the carcase would be extremely thin. The best beef is from oxen of from five to six years of age. As sheep are not used for milking in this country, aged ewes are rarely seen in the meat markets; old rams, however, are by no means uncommon, yielding, of course, poor mutton. Ram mutton is coarse, and often emits an unpleasant smell.

Diseased Conditions of Meat.—The flesh of over-driven animals is said to be injurious, but perhaps the most important question in regard to the wholesomeness or otherwise of meat is how far it is affected by any disease of the animal.

The following are the chief diseases met with or likely to occur in either home-bred or imported animals, and which may be regarded as more or less rendering their flesh unfit for man's food:—

In oxen and sheep:
- Cattle plague.
- Pleuro-pneumonia.
- Anthrax:
  - Boils.
  - Black quarter.
  - Splenic fever.
- Sheep pox.
- Consumption (tuberculosis).
- Actinomycosis.
- Joint-ill or rheumatism.
- Foot-and-mouth disease.
- Liver fluke.
- Hoof-rot.

In pigs:
- Pleuro-pneumonia.
- Typhoid fever.
- Anthrax.
- Foot-and-mouth disease.
- Consumption (tuberculosis).
- Quinsy.
- Cysticerci (measles).
- Trichinæ.

In horses:
- Glanders.
- Farcy.

A few of these affections are parasitic diseases in which the meat or flesh is infected with the young of worms so as to render it unfit for the food of man. With regard to the hurtfulness or not of the flesh of animals affected with general diseases, some variety of opinion exists. The general symptoms resulting from the consumption of such meat are mainly vomiting, diarrhœa, fever, and more or less prostration. In the majority of cases of disease, the meat is dark and moist, usually altered in consistency, and not rarely marked by tastelessness. The precise nature of the poisons which exist in the flesh of animals affected with the above-named diseases is not known, but there is reason to believe that whatever they may be, they are associated with the presence and activity of bacteria. Although there is reason to think that, with few exceptions, these are rendered innocuous by exposure to the temperature of cooking, still this mode of protection is so uncertain that the safest course is to reject for food the flesh of all animals affected with any acute or specific disease.

There is one disease, however, which, owing to its commonness, is deserving of special remark. It is tuberculosis, or consumption, commonly called by butchers "the grapes," or pearl disease. It is common among oxen and pigs, less so among sheep. The disease is marked by the presence of small white tumours or pearls. These occur mainly on or near the surface of the lungs and on the inside of the chest walls, but they may also be scattered through the lungs, liver, and general parts of the body; this latter condition is very rare. Tuberculosis is now known to be associated with, and believed to be caused by, a minute organism called the tubercle bacillus, which is readily carried from one part of the body to another, and consequently is a disease communicable from one of the lower animals to man The Royal Commission on

Tuberculosis (1898) advised that the entire carcase and all organs should be seized in case of—

(1) Miliary tuberculosis of both lungs;
(2) Tuberculous lesions on the pleura and peritoneum;
(3) Tuberculous lesions in muscle or intermuscular lymphatic glands;
(4) Tuberculous lesions in any part of an emaciated carcase.

But only the tuberculous parts need be seized if the lesions are confined to—

(1) The lungs and thoracic lymphatic glands;
(2) The liver;
(3) The pharyngeal lymphatic glands;
(4) Any combination of the above if the lesions are collectively small in extent.

They also advise that foreign dead meat with "stripped" pleura should be seized; and that in the case of the pig the whole carcase and organs should be seized if tuberculous deposit in any degree be found.

The transmissibility of bovine tuberculosis to man has been questioned by Koch. The matter is now under re-investigation by a special Royal Commission. The evidence in support of Koch's view is so unsatisfactory that, until the Commission reports, there should be no relaxation in the taking of proper precautions for dealing with milk from tuberculous cows and with tuberculous meat which may be intended for the food of man.

Mention has already been made that the flesh of animals used as meat is frequently affected with parasites. In oxen—that is, in beef—the parasite, present occasionally, is what is called the *Cysticercus bovis*. It consists of a head or scolex of a tapeworm having attached to it a cystic expansion. Meat containing this cysticercus gives rise in man to a tapeworm called the *Tænia mediocanellata*. A detailed account of this parasite and its life history is given in a subsequent chapter.

In sheep, the chief and most common parasite is the *fluke*, which is a kind of worm, in shape very like a sole fish, only measuring 1 to 1½ inches in length and about ⅜ inch in width. It infests the liver of sheep and occasionally oxen, giving rise to the disease of sheep called "the rot." As cooking always kills the fluke, few cases of disease from this parasite are known in man; but as its presence in a sheep's liver usually causes the animal to be in bad health, the flesh of "rotted" sheep must, as a rule, be regarded as unsound and unfitted for food. Occasionally, both oxen and sheep are affected with the cyst form or cysticercus of the *Tænia echinococcus*, which is a tapeworm whose adult form only affects dogs and wolves. In man, this cyst gives rise to echinococcus

or hydatid disease. A more detailed account of this parasite is given in Chapter VIII.

The presence of cysticerci in meat is generally visible to the naked eye; they are so numerous sometimes as to cause the flesh to crackle on section, or even feel gritty: their real nature is readily seen when the meat is placed under a microscope with low power.

The pig is infested with two parasites, both of which exist in the flesh or pork. One is the *Cysticercus cellulosæ*, which, existing in the pig's muscle as a cyst of the size of a pea or small marble, constitutes the affection known as "measles," and this measly pork when eaten gives rise to a tapeworm in man called the *Tænia solium*. The cysticerci of pork are killed by a temperature of 140° F., and if pork were always properly cooked this would render them harmless; but as no dependence can be placed upon the meat being sufficiently heated and cooked, measly pork needs to be always condemned as unfit for food. The other parasite of the pig is the *Trichina spiralis*. This is a very small immature worm, which is found coiled up inside ovoid cysts, which, of the size of $\frac{1}{70}$ inch, lie imbedded in the pig's muscle. When thus affected, the pork shows a number of small white specks between the muscle bundles, and is said to be trichinosed. As will be explained subsequently, the eating of this trichinosed pork gives rise to the disease called trichinosis in man. Such diseased pork is, of course, unfit for food.

Fish.—As a class, fish vary much in digestibility, this depending practically on the amount of fat they contain. The fatter a fish is the more digestible its flesh. Of the fat group of fishes the best are salmon, herring, mackerel, eels, and sprats; of the non-fatty, the cod is the most commonly consumed specimen. Of the various shell-fish, oysters eaten raw are almost self-digestive, but lobsters and crabs are not only foul feeders, and as such liable to give rise to ill effects when eaten, but also notoriously indigestible. The same may be said of mussels, these fish in particular being at times extremely liable to cause poisonous symptoms, especially when taken from stagnant water to which sewage has access.

To be at their best and wholesome, fish should be in season. During spawning a fish gets flabby and thin, and during this period is rightly regarded as being "out of season" and unfitted for food. A few fish are peculiar in their breeding, such as brill, dory, lobsters, plaice, prawns, soles, shrimps, turbot, and red mullet, which are in season all the year round. Oysters are not in season during the four months spelt without an *r*.

By the Freshwater Fisheries Act, 1878, it is enacted that, subject to special exemption by the Board of Trade for eels,

pollen, trout, and char in certain fishery districts, from March 15 to June 15 shall be a close time for all fresh-water fish.

As in the case of animals, fish when eaten should be fairly fresh. A fresh fish is firm and stiff; the drooping or not of its tail is a fair criterion of freshness in a fish. Flat fish keep better than herrings or mackerel. Cod, haddock, and whiting keep the best, particularly if rinsed with salt water and stored in a cool place. All fish intended for food should be unbruised, unbroken, and clean. If the scales are dull and damaged, it is very suggestive of either ill usage or staleness; softening in places indicates the same. Fish are sometimes affected with a parasite in the form of a cysticercus. This, when eaten imperfectly cooked, gives rise to a tapeworm called the *Bothriocephalus latus*. These diseased fish are rare in this country, but common in Russia, Poland, Sweden, and Switzerland.

Although the great group of fishes yields a larger number of species used as food by man than either birds or animals, and although there are but few fish in British waters which may not be eaten with advantage, still many prejudices exist with regard to their use. This is much to be regretted, as fish are most valuable and important articles of nourishment; if perhaps not possessing the satisfying and stimulating properties that belong to the flesh of birds and quadrupeds, still the health and vigour of the inhabitants of fishing towns, where fish often forms the only kind of animal food consumed, show that it is capable of maintaining the body under active conditions of life. The fish-eating races and classes are remarkably strong and healthy. For the sick or weakly, in whom the powers are too feeble to digest the stronger kinds of animal food, fish possesses valuable properties.

The processes of drying, pickling, salting, and smoking are employed for the preservation of fish. Each process considerably lessens its digestibility, and therefore unsuits it for either the dyspeptic or the invalid.

Eggs.—From the fact that the young chick is developed from it, an egg necessarily contains all that is required for the construction of the body. On this account eggs are often spoken of as typical natural foods. Proteid matter is largely present, under the form of albumin, both in the white and yolk. Fat exists as an oil in the yolk. Carbohydrates exist in the form of minute quantities of a saccharine matter, and water and salts complete the list. The hen's egg usually weighs 2 ozs., but those of ducks and some sea-fowl weigh more. The shell of an egg constitutes some 10 per cent. of the total weight; the white, 60 per cent.; and the yolk, 30 per cent. The white of egg consists chiefly of albumin, with traces of fat and salt; the yolk

consists largely of fat and salts, with a small amount of globulin. Ducks' eggs contain generally more fat than those of hens. Eggs offer a convenient and concentrated article of diet, rich in fat and proteid, but are at times indigestible, particularly if overcooked. They are conveniently preserved by exclusion of their contents from the air, either by coating the shell with oil, wax, or gum. Their condition as to freshness is readily determined by dissolving 2 ozs. of common salt in a pint of water; in this solution a good egg will sink, while a stale or bad one floats.

Milk.—Milk not only constitutes the chief diet for children up to some eighteen months of age, but also enters very largely into the food of adults. All milk may be regarded as nothing more than an emulsion of fat containing proteids, salts, and carbohydrates in solution in water. The average composition of milk per 100 parts, from the chief sources as used by man, is shown in the following table :—

Kind of milk.	Specific gravity.	Total solids.	Proteids	Fats.	Carbohydrates	Salts	Water.
Human . . .	1027	12·60	2·29	3·81	6·20	0·30	87·40
Cow's . . .	1032	12·83	3·55	3·69	4·88	0·7[illegible]	87·17
Mare's . . .	1035	9·21	2·00	1·20	5·65	0·[illegible]	90·79
Ass's	1026	10·40	2·25	1·65	6·00	0·50	89·60
Goat's . . .	1032	14·30	4·30	4·75	4·45	0·75	85·71
Buffalo's . . .	1032	18·60	6·11	7·45	4·17	0·87	81·40

Although all the above are used at times by man for food, the most important kinds undoubtedly are human milk and cow's milk; and these differ from each other in some essential particulars. As seen by the preceding table, while there is more carbohydrate in human milk than in cow's, the reverse is the case with the proteids and salts; the fat being much the same in them both. Ass's milk, except in regard to its fat, is most like human milk, but mare's milk contains even less fat and proteid than the ass's; while, on the other hand, milk from both the goat and buffalo are very rich in fat.

The proteids of milk consist largely of casein; but there is also some albumin, with traces of globulin. The casein probably exists in milk in combination with phosphate of lime, which helps to keep it in solution. Pure casein is now prepared on a large scale, and constitutes the basis of a number of dietetic preparations, such as Plasmon, Protene flour, Sanose, Nutrose, and Eucasin. The nutritive value of these preparations is high, as they contain fully 90 per cent. of pure proteid. In these forms

casein is digested easily, and capable of replacing all other forms of proteid in the diet.

The salts of milk are both numerous and various, being composed really of all the mineral constituents necessary to the growing body.

The fat of milk is nothing more than minute oil globules suspended in the milk, and which, upon standing, rise slowly to the surface, forming cream. One part of cream is said to correspond to 0·2 of fat roughly; the proportion of cream yielded by a pure milk varies, but may be said to average 10 per cent., being as high as 14 in some cases, and as low as 6 in others. The amount found in a given time is no measure of the richness of the milk; water added to milk causes a more rapid separation of the cream. When milk is subjected to centrifugal action, as in the *separator* so largely used now in commercial dairies, a much larger proportion of cream is obtained than by the mere skimming process. As a result of this, skim milk contains 1 per cent. of fat, while separated milk has practically none.

The carbohydrate of milk is a peculiar sugar, somewhat like cane-sugar, and called lactose, or sugar of milk. This body, like all other sugars, undergoes fermentation under the influence of micro-organisms, and one especially, called the *Bacterium lactis*, abounds in dairies and other places where milk is kept. This micro-organism converts the milk-sugar into lactic acid, while at the same time the proteids are partly decomposed and partly coagulated, the milk itself becoming sour with enclosure of the fat in the coagulated casein. Many other micro-organisms produce coagulation of milk, notably the *Bacillus butyricus* of butyric acid fermentation. Some others have the power of changing the colour of milk, particularly if lactic acid fermentation has occurred. Thus the *Bacillus cyanogenus* causes blue milk; the *Bacillus synxanthum* causes yellow milk; the *Micrococcus prodigiosus* produces red milk; while other bacteria at times cause milk to become ropy and stringy. In nearly all these cases, the milk is apt to cause diarrhœa, and is unsuited for food. Alcoholic fermentation of the milk-sugar can also be set up by certain micro-organisms. "Koumiss" is the result of the alcoholic fermentation of mare's milk, and "Kefir" is that of cow's, goat's, and sheep's. After the lactic acid fermentation of milk has set in, the casein gradually decomposes, and, during the early decomposition of the proteids, very frequently highly poisonous compounds are formed, such often being the cause of the violent poisonous effects which at times are produced by ice-creams and other articles of food into the making of which milk enters.

Although boiling undoubtedly destroys bacteria and other

micro-organisms in milk, it affects seriously the physical and nourishing qualities of this food. Boiling of milk produces coagulation of the lact-albumin, some obscure changes in the sugar, and greater coalescence of the fat globules; at the same time, the proteids are modified, and rendered apparently less digestible, the salts are less soluble, and the natural ferments are destroyed. The chief chemical change in the salts is probably the conversion of the soluble bi-citrate of calcium into a less soluble tri-citrate. Most authorities agree that boiled milk has less nutritive value than that which is fresh, and that the indiscriminate feeding of infants for months upon carelessly boiled or heated milk is productive of much harm. A discrimination needs to be made not only as to means of heating milk, but also between degrees of heat to which it is raised. Milk warmed in a vessel exposed directly to the fire loses at 85° C. some 28 per cent. of its lecithin, but when heated to the same point in a *bain-marie*, it loses only about 12 per cent. In the same way direct heating of milk over a fire to 85° C. reduces the citric acid nearly a third, while if heated to the same temperature over a water bath the loss of citric acid in solution is but 5 per cent. It would appear that up to 70° C. no apparent changes are produced in milk; at 70° C. the albumin begins to be affected, not actually coagulated, but converted into a form which is easy of precipitation by acids, sulphate of magnesium, and other precipitants of casein. At 80 C. milk tends to alter in flavour and certain organized ferments undergo retrograde changes; at 85° C. the calcium citrate is thrown out of solution. The remedy seems to be to avoid routine boiling of milk over naked fires, but to heat the milk in a water bath or *bain-marie* to not more than 75 C. (160° F.), and maintaining it at that temperature for twenty minutes or so. This will entail more trouble for mothers and nurses, but the recognition of the principle is the only basis for sound practice.

The actual composition of cow's milk is influenced by not only the breed of the animal, but also by the kind of feeding, and the time of calving and milking. The effect of diet is largely shown by the increase of sugar found in the milk of cows fed upon fodder rich in carbohydrates, such as carrots and beetroot. The addition of proteid in the diet raises the casein, but not the fat. The colostrum, or milk of cows recently calved, is poor in sugar, but rich in casein and albumin. The first part of a yield during milking, known as fore milk, is deficient in fat, but the latter part, called the strippings, is very rich in cream.

It is well known that in human beings, bitters and purgatives, if taken by the mother, act upon infants taking the milk. Diseased potatoes and turnips in the food of cattle, without actually

affecting the goodness of milk, often cause it to smell and taste unpleasantly; other fodders often produce poisonous effects, as in goats feeding upon meadow saffron inducing severe diarrhœa, or in the case of cows affected with "trembles," due to eating the *Rhus toxicodendron*, their milk gives rise to vomiting and constipation. Milk allowed to stand long in warm dirty rooms has a remarkable power of absorbing effluvia, rapidly become sour and objectionable, and is a fruitful cause of diarrhœa occurring among the children of the poor.

Milk may be affected by diseased conditions of the cow or the animal yielding it. In foot-and-mouth disease, cow's milk varies very greatly; but a constant feature of such milk is the great excretion of serum albumin. Milk of cows affected with foot-and-mouth disease should never be consumed as food, as it may cause disease in human beings. Tuberculosis in cows undoubtedly affects the milk yielded by them, particularly when the teats are tuberculous, and such milk, if consumed, may lead to the same disease (consumption) in man. There is reason, too, to think that both scarlet-fever, diphtheria, and enteric fever, and also cholera, are in many cases propagated by means of milk, the milk becoming infected, either direct from the animal, or by the use of water impregnated with the poison. Since boiling the milk invariably destroys the specific micro-organism associated with these and other diseases, this procedure should be invariably done as one of the most reliable measures against diseases arising from the use of milk.

Adulterations of Milk.—The chief adulterations of milk are the additions of water and the removal of cream; while carbonate of soda, salt, formaldehyde, boracic acid, or salicylic acid, glycerine, and starch are added, either to preserve the milk or to mislead the analyst. A common procedure is to remove part of the cream, which would naturally raise the specific gravity, and then, by adding water, to bring the specific gravity down to the normal. The addition of water lowers the specific gravity, the fat, solids not fat, and the salts per cent. This added water can be sometimes detected by taking the specific gravity of the milk by means of a lactometer, which should be done at a temperature of 60° F.; if at a higher or lower temperature than this, 1° of specific gravity must be deducted or added for every 10° of heat. In good milk, the specific gravity is from 1028 to 1034; while, in creamed milk, it is from 1033 to 1037; that is to say, it is lowered by watering and increased by skimming. This taking of the specific gravity alone is not to be relied upon as an index of the character of the sample, but should be taken in conjunction with the facts relating to the fats and total solids.

The total solids can be estimated by taking a weighed quantity of milk, and evaporating it slowly to dryness, and re-weighing. Usually 2·5 c.c. of milk are taken for this estimation, and in good milks the total solids should not be less than 12 per cent. The fat in a good milk should not be below 3 per cent.; it is conveniently estimated by mixing a weighed quantity of milk with a weighed amount of burnt gypsum, and evaporating to dryness. The fat is extracted from the residue by ether, and the ether then evaporated, when the residue is again re-dried, re-weighed, and calculated out as fat per cent. For the more rapid and routine estimation of fat in milk samples, the employment of a centrifugalizing machine and the use of the Leffmann and Beam process will be found satisfactory. Fifteen c.c. of the milk are placed in the special glass bottle supplied with the centrifugalizer; 3 c.c. of a mixture of equal parts of fusel oil and strong hydrochloric acid are added, and then 9 c.c. of pure sulphuric acid. These latter must be added slowly, about 1 c.c. at a time, and the contents of the bottle carefully shaken. The milk will gradually assume a chocolate colour passing to a deep brown, and at the same time much heat be generated. When the whole of the 9 c.c. of acid have been added, the contents of the tube or bottle must be filled up to the zero mark with a hot and freshly made mixture of one part of strong sulphuric acid with two of water. The bottle should be placed in one of the carriers of the machine, and whirled for at least two minutes. If only one sample of milk is being tested, the opposite carrier must be balanced by a corresponding bottle filled with dilute sulphuric acid. A milk poor in fat may need centrifugalizing for four or five minutes, but usually two minutes is enough: very rapid rotation is not necessary. On stopping the centrifugalizer and taking the bottle out of the carrier, the fat will be seen to have separated out as a layer on the top, and as the bottle is so made that each mark represents 1 per cent. of fat, the total percentage of fat in the sample is readily read off. This method is subject to an error of about 0·1 per cent., but its rapidity and ease render it a valuable and reliable means of fat determination. The amount of fat so determined deducted from the total solids gives the "solids not fat," and as the result of many analyses, these are found, with very rare exceptions, not to fall below 8·5 per cent. Hence this amount is adopted as a standard, and if a given milk sample contains x per cent. of solids not fat, and x be less than 8·5, we are justified in presuming that, however poor the milk may have been to begin with, it must now have added water in it. Thus, presume a given sample of milk has yielded 3·5 per cent. of fat, and 10·5 per cent. of total solids. The solids not fat are obviously

7 per cent., and working upon the above-mentioned minimum standard of 8·5 for solids not fat, we get the following formula: $\frac{100 \times 7}{8 \cdot 5} = 82 \cdot 35$ parts of original or genuine milk in a 100; or, in other words, over 17 per cent. of water may be presumed to have been added to the sample. The ash of a good milk rarely falls below 0·7 per cent., and accepting that as a minimum standard, a similar equation can be stated, if the observed amount of ash be known, as a means of calculating the degree of purity of any particular milk. The ash of milk is, of course, estimated by incinerating the total solids of a given bulk of milk, weighing and expressing as a percentage.

Sugar in milk is easily determined by first precipitating the casein, by means of acetic acid, from 10 c.c. of milk; filtering, and then diluting the filtrate or whey with distilled water to 100 c.c. This diluted whey contains the lactose or milk-sugar in solution, and is next treated with a solution of copper until all the copper is reduced to red suboxide, and no blue colour remains in the liquid. The copper solution is so made that 10 c.c. are decomposed by 0·0667 grm. of lactose.[1] If, say, 15 c.c. of a ten-times diluted whey are required to reduce 10 c.c. of copper solution, then $\frac{15}{10}$, or 1·5 c.c. of the original milk are needed to reduce that amount of copper solution, and 0·0667 grm. lactose ÷ 1·5 = 0·0445 grm. of lactose in 1 c.c. of milk, or 4·45 per cent.

The presence of added glycerine in milk can usually be detected by the exceptional sweetness of the dried solids, but for the detection of such preservatives as boric acid, salicylic acid, sodium carbonate, and formaldehyde in milk, the following tests need to be applied:—

Boric Acid.—Reduce 25 c.c. of the dried milk to an ash slowly in a capsule, add a few drops of hydrochloric acid, sufficient to render it distinctly acid, and then 25 c.c. of distilled water. Now dip strips of turmeric paper in the mixture and dry them over a flame. If boric acid be present the turmeric paper will turn a crimson red, which on the further addition of sodium carbonate turns blue.

Salicylic Acid.—Agitate 10 c.c. of the milk in a test tube with 0·5 c.c. of dilute sulphuric acid, so as to thoroughly break up the clot and produce a homogeneous mixture. Next shake with

[1] Take of pure copper sulphate 34·64 grms., and dissolve in 500 c.c. of distilled water; this is stock solution A. Take also 173 grms. of the tartrate of sodium and potassium, with 56 grms. of caustic soda, and dissolve in 500 c.c. of distilled water; this is stock solution B. When required for use, take 5 c.c. of each solution and mix. One c.c. of this solution is reduced by 5 mgms. of either glucose or inverted sugar; and by 6·67 mgms. of milk-sugar or lactose.

10 c.c. of ether, allow this to separate, and transfer to either a capsule or another test tube; slowly evaporate the ether at say 75° C., and then dissolve any salicylic acid which may be present in the residue by boiling with 10 c.c. of rectified spirit. Now add some ferric chloride solution and shake. If salicylic acid be present a violet colour will be produced.

Sodium Carbonate.—Mix 10 c.c. of milk with 10 c.c. of rectified spirit in a test-tube, and then add two or three drops of a weak solution of rosolic acid, made by dissolving 1 grm. in 25 c.c. of alcohol, and diluting with distilled water to a litre. If the alkali be present in the milk, a rose-pink tint appears.

Formaldehyde.—Place about 10 c.c. of the milk in a test tube, add to it 2 c.c. of a 10 per cent. solution of caustic potash and 1 c.c. of a saturated solution of phloroglucine. If formaldehyde be present a fleshy pink colour is produced.

The question of preservatives in milk and milk products was considered by a Departmental Committee of the Local Government Board appointed in 1899. As the result of its inquiry, that committee recommended that boracic acid preservative, provided the admixture were duly notified by label, might be allowed to be mixed in cream to a limited extent, namely, not exceeding $\frac{1}{4}$ per cent.; and in butter, without notice by label, to a somewhat larger extent, namely, up to $\frac{1}{2}$ per cent., but not more; but that no other kind of preservative should be used with either cream or butter. It was also recommended that in the case of all dietetic preparations intended for the use of invalids or infants, chemical preservatives of all kinds should be prohibited; and it was especially recommended that the use of any preservative whatever in milk should be constituted an offence under the Sale of Food and Drugs Act. It is to be regretted that no statutory action has been taken in this matter, as there can be no doubt that the indiscriminate use of preservatives in milk, and the wholesale consumption of such chemically treated milks by young children, is productive of a great deal of harm. Formaldehyde in particular seems to be objectionable as it so alters the proteids of milk as to render them largely indigestible.

As an outcome of the Report of a departmental committee appointed by the Board of Agriculture to inquire into the desirability of making regulations as to the sale of milk and cream, an Order by the Board, under Section 4 of the Sale of Food and Drugs Act, 1899, came into force on September 1, 1901, whereby a presumption is raised that milk (not being sold as skimmed or separated, or condensed milk) is not genuine unless it contains 3 per cent. of milk fat and 8·5 per cent. of milk solids other than milk fat. Further, where a sample of skimmed or separated milk

(not being condensed milk) contains less than 9 per cent. of milk solids, it shall be presumed, until the contrary be proved, to be not genuine. By this order the principle of standards for food becomes officially recognized.

We cannot leave this subject of milk without calling attention to the urgent need of a reform of the country's milk supply. Associated as it closely is with the problem of infant mortality it constitutes a national question of the first importance. The problem of milk supply is really threefold, namely, (1) to prevent initial pollution at the time of milking; (2) to protect milk from subsequent fouling, either during transit to or storage in the home of the consumer; and (3) it must be produced at a price which will bring it within the reach of the poor. To prevent the first, attention must be directed to the farm. The cows must be healthy, and housed in byres or sheds so planned and constructed as to permit of these cattle remaining healthy. Further, the process of milking must be carried on with scrupulous cleanliness of cows, milkers, and all utensils. The second line of prevention must ensure that milk, immediately after milking, be maintained at a temperature not exceeding 40° F., and that as soon as possible after cooling the milk be bottled, and the bottled milk be kept at even a lower temperature, say 35° F., until it is delivered to the consumer. By the precautions during milking the initial contamination is minimized, and bottling would minimize home contamination. The third essential, or safeguarding of price, can only be obtained by the municipalization of the milk supply.

The present position of the law, and details as to the legal provisions existing already for controlling milk supplies, are given in Chapter XI., but there is little doubt that further legislation is urgently necessary on the following lines: (1) To empower urban and rural sanitary authorities to inspect, in regard to tuberculosis and any other disease, cows and cowsheds, wherever situated, from which milk is supplied to their districts. (2) To amend and extend the provisions of the Dairies, etc, Orders so as to make applicable to tuberculosis their regulations concerning the inspection of cattle; to prohibit the use of milk from cows having tuberculous udders as food for animals, unless first boiled; to prohibit the stalling of cows in byres not conforming to the following conditions: Every cow to have 800 cubic feet of air-space, with 50 square feet of floor-space and 3 square feet of window. Each cow to have a separate stall with division block not less than 4 feet in height. Running the entire length of the byre, and immediately in rear of the cows, should be a manure channel 1½ feet wide and 6 inches in depth, having a fall of 1 in

20. The feeding-troughs to be of stoneware, with a space of 3 feet between the wall and the head of the cow. Floors to be of impervious material, and walls covered with cement to their full height. An adequate supply of water to be available. Ventilation to be provided by inlets at either end of building and between each pair of stalls by means of windows falling in at top, and outlets by extraction shafts in centre of roof. The manure channel should be provided with a ventilated trap located outside the byre, but between it and the sewer or manure pit. Every byre should have a boiler for the washing and scalding of utensils, and further have no direct communication with the milk store.

Butter.—This really is the fat of milk clotted together, and consists chiefly of neutral fats mixed with water and small amounts of casein and salts. Average butter may be said to have the following composition per cent.: Fat, 78 to 94; curd, 1 to 3; water, 5 to 14; salt, 0 to 7. The flavour of a good butter is due to butyric and caproic acids, which constitute about 8 per cent. of the fat, the rest being composed of glycerides of oleic, stearic, and palmitic acids. The water in a good butter should not exceed 16 per cent., an excess lessens the keeping quality of the butter; it contains ordinarily in solution milk-sugar and the milk-salts. Common salt is usually present, but generally added after the butter is made. Artificial colouring matters are often present in butter, notably annatto, but it is harmless; occasionally starch is added to give weight, and may be recognized by its blue reaction with iodine. Practically the only adulteration in butter is the substitution of foreign fats, such as tallow, lard, palm-oil, rape seed oil, or cocoa-nut oil, for milk fat; and as a result the analysis of a butter turns mainly upon the properties and composition of the fat.

The amount of fat can be estimated by dissolving it in ether, evaporating the ether solution, drying, and weighing. For the detection of an admixture of foreign fats, several methods have been proposed; the principal being: (1) Taking the specific gravity of the sample. That of water being unity, a pure butter usually has a specific gravity of 0·911 to 0·913; an adulterated butter one of 0·902 to 0·904; and an artificial butter one as low as 0·859 to 0·861. (2) Determining the melting-point of the fat after separation from the other constituents. The melting-point of pure butter fat is 95° F., but may vary; the addition of animal fats, such as lard, raises the melting-point, while vegetable fats, such as rape-seed oil, tend to lower it. (3) Determination of the fixed fatty acids. This, though rather a difficult process to do, is most generally relied upon. It is based on the fact that when saponified with a caustic alkali such as soda or potash, and then decomposed with hydrochloric acid,

the individual fatty acids which go to make up butter are obtained. A certain number of these are soluble in water, and others are not, and it is owing to the insoluble fatty acids obtainable from butter differing in amount from those obtainable from other animal fats that pure butter can be detected from artificial, the figures being, that if the insoluble fatty acids are over 89 per cent. there is an admixture of foreign fat.

Of artificial butters there are several; but in their manufacture they are very similar, consisting really of a certain amount of genuine butter mixed up with animal or vegetable fats, such as lard, rape-seed oil, etc. By the law of 1881, all these artificial butters are ordered to be called and sold as *margarine*; in the United States they are termed oleo-margarine. If made from pure animal fats, these artificial butters have as high a nutritive value as pure butter. The average melting-point is 86° F., and the insoluble fatty acids contained in them are usually as high as from 92 to 95 per cent., as compared with 88 or 89 per cent. in pure milk butter.

Cheese.—This is made from milk by the action of rennet, which is commonly derived from the fourth stomach of the calf. Cheese consists of coagulated casein, with varying proportions of fat and salts. The different qualities of cheese depend mainly upon whether they are made from pure milk, from skimmed milk, or from a mixture of skim and whole milk. Thus, Cheddar, double Gloucester, Cheshire, and some American cheeses are made from whole milk, while Stilton is made from whole milk to which cream is added. Dutch, Parmesan, Suffolk, and Somersetshire cheeses are made from skimmed milk. Cream cheese consists of the fresh curd which has been moderately pressed; it is eaten without being allowed to ripen. When a cheese is kept, it undergoes a change known as "ripening," which is essentially a decomposition, whereby the casein undergoes a fatty change, including the formation of lime salts of the fatty acids and the production of a soluble compound of phosphoric acid with casein, from the phosphate of lime usually present in milk.

As an article of diet, cheese is very useful, being particularly rich in both proteid and fat; the only objection to it being its occasional indigestibility. Its adulterations are unimportant, the chief being starch, to give weight. On an average, the water in cheese ranges from 20 to 35 per cent., the proteid from 25 to 50 per cent., the fat from 12 to 20 per cent., and the salts some 3 to 6 per cent. Cheeses usually contain small amounts of milk-sugar, lactic, and other organic acids. The richer kinds of cheese are very liable to form the seat of growth of certain animal and vegetable organisms. The maggots or larvæ of a fly (*Piophila*

casei) are well known, so also is the cheese mite, or *Acarus domesticus*. The mould on a cheese is composed of minute vegetable organisms of the fungus tribe; the red mould is caused by *Sporendonema casei*, and the blue mould by *Aspergillus glaucus*.

Vegetable Foods.--This large group, which includes a great number of articles of diet, is chiefly remarkable for the fact that although it supplies a certain quantity of proteid and fat, its chief functions are for the provision of carbohydrates, vegetable acids, and salts to the organism. Further, owing to the large amount of water which vegetable foods take up during cooking, they may also be said to supply a large quantity of water to the body. The proteids of vegetables are mainly in the form of globulins and albumoses; the most important of them being *glutin*, which is largely present in wheat-flour. Glutin does not exist as such in wheat-flour, but is formed from the globulin and albumose, naturally present, by the action of water. Glutin being readily digested, forms a very valuable proteid food; it can be obtained also from rye-flour, but less easily than from wheat. *Legumin* and *conglutin* are other proteids found chiefly in the Leguminosæ, or peas and beans. These proteids are like glutin, derived by the action of water from the globulin and albumose present in the grains. The fats yielded by vegetable food are very small in quantity, and, from a nutritive point of view, quite unimportant.

The carbohydrates, either as starches, gums (dextrine), or sugars, constitute the chief part of all vegetable foods. In the cereals, potatoes, peas, and beans, starch is the chief carbohydrate, coupled with small quantities of sugars or dextrines. In beetroot and sugar-cane, of course, cane-sugar is the carbohydrate, while in the ripe fruits it exists in the form of glucose or grape-sugar. The starches are a large class, and vary as much in the size, form, and structure of their grains as they do in their origin, which embraces not only wheat, oats, barley, rye, maize, peas, beans, and potatoes, but includes the various forms of arrowroot, tapioca, and sago. In its uncooked state, a starch grain is hard and not easily digested; it is composed of two bodies called *granulose* and *erythrogranulose*, enclosed in cellulose coverings. Granulose, which constitutes the greater part of the starch grain, turns blue with iodine, the erythrogranulose turns red with the same, while the cellulose is turned yellow by iodine. Moist heat causes the cellulose coat to burst, so that the grain swells up and the starch is set free. Starch grains have in the majority of cases a sufficiently characteristic appearance, under the microscope, to indicate their origin, and it is upon their peculiarities of size and form that the various adulterations of the starches by other kinds is best detected. Wheat-flour being the most important, is the

kind most usually adulterated with other varieties of starch. To examine a starch under the microscope, it is sufficient to moisten a little of it in a state of fine powder with a drop of water or glycerine upon a glass slide. When so examined, they can be conveniently divided according to their appearance into two groups: (1) a group in which their contour is even; this includes wheat, rye, barley, pea, bean, the arrowroots and potato; (2) the other group is one in which, instead of the contour being even, it is marked by facets or surfaces, either completely, as in oats, maize, and rice, or only partially so, as in tapioca and sago. The chief characteristics and appearance of the various starches will be noted in the subsequent figures.

The vegetable foods as a class yield excessive quantities of phosphates and potash as compared with the animal foods, which are particularly rich in chlorides and soda; on this account, common salt or chloride of sodium is a special need among vegetable feeders. Iron is usually present in most cereals, particularly in wheat, in which it exists mainly as a phosphate.

Wheat which is grown in this country is a kind known as *Triticum vulgare*; the grain is surrounded by four coats, each of which is composed of special shaped cells. Within these coats is the grain proper containing the starch, fat, proteid, and salts. The starch grains of wheat (Fig. 24) are very unequal in size, some being very large, and others small; the large ones have a central spot, or hilum, and are marked by faintly concentric rings; the smaller ones are often angular. In the process of milling, the various coats of the wheat grain are more or less removed and separated as bran, the inside of the grain being ground up so as to constitute flour of the best quality. In the second-rate flours, this separation of the bran is less perfectly carried out, the result being a wholemeal flour of a dark colour. Wheat-flour is rich in proteid and carbohydrate, but poor in fat and salts. Its proteid, as already explained, exists as a globulin and an albumose, and from these, by the action of water, glutin is formed. The amount of glutin obtainable from a flour is a test of its quality and suitability for bread-making; usually this amount is from 8 to 12 per cent. Its contained water should not exceed 16 per cent.; the more water present, the less the keeping quality of the flour; the salts are chiefly phosphates of potash and magnesia. A good flour should be white in colour and free from

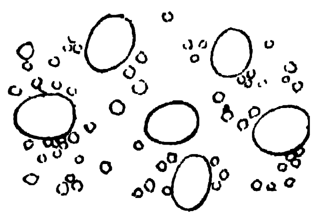


FIG. 24.—Wheat starch.

mouldy smell or acidity. It is occasionally adulterated by mixture with other starches, notably potato and rice starch; these can be readily recognized with the microscope. Both animal and vegetable parasites occur in flour, and can usually be detected by microscopical examination. The more common animal parasites are the weevil (*Calandra granaria*), the mite (*Acarus farinæ*), and one or more kinds of moth belonging to the micro-lepidoptera. The commonest vegetable parasites of flour are various fungi; one called *Puccinia graminis*, constitutes mildew or red rust of wheat, and whose ripe sporangia show themselves under the microscope as dark-brown club-shaped bodies filled with spores; another parasite is bunt, caused by the *Tilletia caries*, which microscopically appears as round reticulated cells. Another fungus, called *Ustilago segetum*, causing smut, is more common in barley or oat-flour than in wheat. Its spores or seeds are smaller than those of bunt, being also circular, nucleated, and not reticulated. The chief preparations of flour are bread, biscuits, macaroni, and vermicelli.

Bread.—The best bread is made from white wheat-flour, but brown and wholemeal breads are made from flours which contain more or less of the bran or wheat-grain coats. The disadvantages of wholemeal bread are, first, its dark colour, and next, the irritating and digestible qualities of the cellulose of the bran. On the other hand, if we take bran as forming 16 parts of the grain, we have an addition to the bread, by inclusion of the bran, of some 0·7 per cent. of proteid and 0·16 per cent. of salts.

Bread is made by mixing flour with water and kneading it so as to form dough by the cohesion of the glutin. To this dough is added a ferment or leaven, usually consisting of a mixture of potato, flour, and brewer's yeast. The addition of this leaven gives rise to a ferment action on the starch, whereby alcohol and carbon dioxide gas are formed in the dough, resulting in the latter becoming broken up and perforated by innumerable holes. During baking, a certain quantity of sugar and dextrine is formed from the starch, while too, in consequence of the full aeration of the dough, the bread mass becomes light and digestible. In some bakeries, in place of using leaven or yeast, powders consisting of tartaric acid and bicarbonate of soda are added in order to generate the necessary carbon dioxide. In another system, known as Dauglish's, the carbon dioxide is generated separately by the action of sulphuric acid on marble, and the resulting dioxide gas forced into the dough by pressure. It is claimed for these unfermented breads that they have the advantage of containing no alcohol, acetic acid, and other bodies, the products of yeast action. This may be the case, but, on the other hand, the action of yeast

is largely a digestive one, by which the starch is changed into maltose and dextrine, and some of the proteids into albumoses, or even peptones.

A good bread should be white in colour; any yellowness is suggestive of either an old flour, bad yeast, or a mixture of rye or bran. The acidity of bread should not exceed 0·18 per cent., and the whole loaf should be permeated in every part with small regular holes. Its contained water should not exceed 50 per cent., nor the ash be over 3 per cent. Alum is occasionally added to bread to improve the colour and check fermentation, any excess over 10 grs. per 4-lb. loaf being regarded as an adulteration. It is roughly detected by pouring upon a slice of bread some freshly made decoction of logwood chips and then a solution of carbonate of ammonia. If pure, the bread is only stained pink; if alum be present, a marked blue to violet colour is produced. The estimation of the precise amount of alum in bread involves a somewhat lengthy process which is beyond the scope of this book. Although bread differs somewhat in composition from flour, its disadvantages as a food are more or less the same, namely, too little fat and too little sodium chloride or salt. In daily life, the deficiency of fat is made up by eating butter, dripping, or bacon with bread, while in the baking half an ounce of salt is added for each 4 lbs. of dough.

A variety of fancy and patent breads are in the market. The various kinds of Vienna bread are good examples of the former class. These are made from fine flour, milk being added to the dough, and fermentation secured by compressed yeast. Of the patent breads, most are brown in colour, and are made from flours prepared by patent processes. Hovis bread is a well-known example; this is made from flour containing considerable amounts of the "germ" of wheat. The germ is a part of the wheat grain rich in fat and proteid. In the milling of ordinary flour the germ is discarded as offal. Being made from flour which contains some of the most highly nutritive parts of the wheat, Hovis bread naturally possesses an enhanced nutritive value. Some other breads are malted. In their preparation malt extract, which contains the ferment diastase, is added to the dough at any early stage before baking. The diastase converts the starch of the dough into malt sugar and dextrin, or, in other words, more or less digests it. Such bread tends to keep moist. Bermaline bread, made by Montgomerie's process, belongs to this group. The diastatic ferment is, of course, killed or rendered inactive during actual baking.

Biscuits.—The ordinary kinds are nothing more than well-baked mixtures of flour and water, though the more fancy varieties contain often milk, butter, and eggs. Owing to the absence of

yeast in their preparation, biscuits do not contain the products of its action upon the carbohydrates and proteids of flour. Taking weight for weight, biscuits contain more nourishment than bread, but are apt to be indigestible and monotonous if consumed for long.

Macaroni and Vermicelli.—These are both preparations of flour. They are made chiefly from the flours of the hard wheats of France and Italy, which are particularly rich in glutin. They are very valuable foods, being distinctly of higher nutritive value than bread.

Barley very closely resembles wheat in its composition, but differs somewhat in the character of its proteids. These do not on the action of water form glutin, but remain in a soluble form as globulin, albumin, and albumose. It is difficult to say how far this affects its nutritive value, but it undoubtedly affects the capability of barley being made into bread, and as such largely used as an article of diet. Its starch grains resemble both in size and appearance those of wheat, but their rings or markings are more distinct. When the whole barley grain is ground, it forms *barley-meal;* when deprived of its husk, and roughly ground, it constitutes *Scotch*, *milled*, or *pot barley*.

Pearl barley is the grain deprived of the husk, rounded and polished by rubbing. So-called *patent barley* is merely pearl barley crushed to the state of flour. Barley water is prepared from pearl barley, and forms a slightly nutritive liquid for infants and the sick. *Malt* is the product yielded when barley has been allowed to germinate, and the germination stopped at a certain point by exposure to heat on a kiln. As a result of this process, the starch of the grain is largely converted into sugar by the development within the barley grain of a peculiar active nitrogenous ferment called diastase. It is from malt that beer is largely made. There being little or no glutin in barley, it cannot be made into ordinary bread; when barley bread is made, it is usually from a mixture of barley-meal with wheaten flour. Barley cakes are eaten in some places on the score of economy; but, as compared with those made from wheat, are less palatable and less digestible.

Rye.—Although little used in this country except for malting, rye in the northern countries of Europe is largely used for making bread. In its percentage composition, rye closely resembles wheat, its proteids forming, on the addition of water, a kind of glutin. Rye bread is dark in colour, somewhat heavy and very acid; but falling little short of wheaten bread in nutritive value. Rye bread is indigestible and apt to cause diarrhœa. If mixed with two parts of wheat-flour, rye-flour makes an excellent bread. The starch grains of rye are very like those of wheat or barley; but,

however, have usually a hilum which is star-shaped, while some of the grains are very large in size (Fig. 25). The common rye is a very hardy cereal, and is commonly sown in soils which are too poor to grow wheat. Rye is subject to a very peculiar fungus disease, by which the grain is enlarged and turned black, producing what is known as ergot of rye. The cause of the disease is a fungus called the *Claviceps purpurea.* When the ergot gets mixed with healthy rye, it becomes mingled with the bread, and leads to a disease in men called ergotism, the symptoms of which are vomiting, diarrhœa, followed in severe cases by either loss of sensibility, gangrene, or paralysis. This disease is practically unknown in this country, and much less prevalent now than formerly abroad. On account of the excessive size which ergotized rye grains attain, they can be separated by sifting from the unaffected seed: when the grain has been ground into flour, the ergot may be detected either by the microscope or by making of it a paste with an alkali, and then adding nitric acid to excess; on neutralizing, if ergot be present, a violet-red colour is produced.

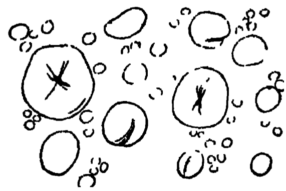


FIG. 25.—Rye starch.

Oats.—As met with in commerce, oats consist of the seeds of the *Avena sativa* enclosed in their husks. When deprived of this integument, the grain goes by the name of *groats*, or *grits*, used in making porridge; and these groats, when ground down fine, constitute *oatmeal*, from which gruel is made. Of all the cereals, oats rank next to wheat as articles of food, being noticeable for containing large amounts of proteid and fat—particularly the latter. Oats resemble barley rather than wheat, in that their proteids do not form gluten on the addition of water; on this account oatmeal cannot be vesiculated and made into bread like wheaten flour. It is, however, made into thin cakes by mixing into a paste with water, and then baking on an iron plate. Owing to the large amount of cellulose which they contain, this is apt to irritate the intestines, and more or less interfere with digestion. The grains of oat starch (Fig. 26) are minute and faceted, often tending to collect together into groups or compound grains. In the form of oatmeal, oats can be taken for long periods without distaste, and in this form constitute a material part of the dietary of the Scotch peasantry.

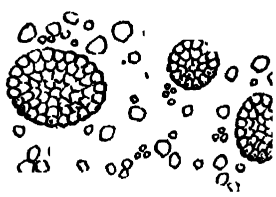


FIG. 26.—Oat starch

Rice.—The common rice, or *Oryza sativa*, is extensively cultivated in India, China, West Indies, Central America, and in some parts of Southern Europe. Its starch grains (Fig. 27) very closely resemble those of oats. Rice is a peculiar grain food, inasmuch as it is remarkably poor and deficient in proteids, fats, and salts. For this reason it needs to be combined with meat, peas, or beans, to supply the proteid with fat, and common salt. It is essentially a carbohydrate food, and, if properly and sufficiently cooked, is very digestible. It is best cooked by thoroughly steaming; if boiled in water, it loses some of its already small quantity of proteid and saline matter. It cannot be made into bread, but is much used in France for mixing with wheaten flour to make the very white bread which is in request in that country.

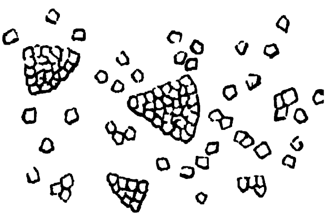


FIG. 27.—Rice starch.

Maize.—Though not much used in England, maize, or Indian corn, is an important food in America and in Italy, where it is called *polenta*. In its nutritive value, maize resembles oats, containing a large quantity of fat. When made either into cakes or porridge, it affords a valuable food. Maize, being deficient in glutin, does not make good bread; it is, moreover, harsh in flavour. This defect is largely removed by treating it with caustic potash, a procedure which is the foundation of the process for making it into the common commercial articles extensively sold under the names of oswego, cornflour, and hominy. If imperfectly cooked, or at all decomposed, maize may give rise to very disturbing symptoms. The grain, too, is liable to a peculiar disease due to a fungus called *Sporisorium maidis*, which gives rise to a disease in man known as "pellagra," and closely resembling scurvy. This affection in not uncommon in Lombardy, where much maize is eaten as food. The starch grains of oats, rice, and maize somewhat resemble each other, in being all of them faceted. The maize starch grains (Fig. 28) are much larger than the other two, with a distinct hilum; oat and rice starch grains are smaller than those of maize, and are usually without a hilum, while both the oat and rice grains have a tendency to collect together into clumps.

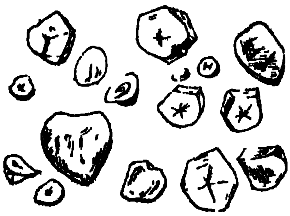


FIG. 28.—Maize.

Peas and Beans.—These belong to the leguminous group of seeds, which also includes lentils. They have a high dietetic value, in consequence of the large amount of proteid which they contain; this is called *legumin*, or vegetable casein, and exists largely in combination with sulphur and phosphorus. Both peas and beans are less digestible than the cereals, and require to be boiled slowly for a long time. Added to rice, foods of this class largely furnish the nitrogenous material in the diets of the natives of Hindustan; but to those unaccustomed to such, it is doubtful whether leguminous seeds can replace the animal proteids. Their large amount of contained proteid adapts them for consumption in association with starchy and fatty articles; a familiar example in our own country being beans and bacon. Unfortunately they are difficult of digestion. The starch grains of peas and beans (Fig. 29) are characteristic, being oval or kidney-shaped; they have no clear hilum, but usually a deep central longitudinal cleft, or at times an irregularly shaped depression. The addition of hot water to pea or bean flour causes the emission of the typical beany smell. Closely allied to the foregoing foods are the potato, the various arrowroots, sago, and tapioca.

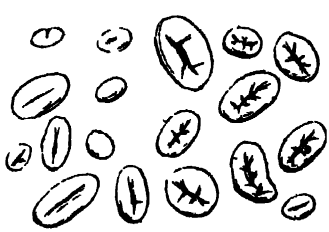


FIG. 29.—Pea flour.

Potatoes.—These may be considered as occupying a place next in importance to the seeds of the cereals as articles of vegetable food. The potato, used as food, constitutes the tuber or exuberant growth of a portion of the underground stem of the *Solanum tuberosum*. The tuber develops into a thick fleshy mass, retaining its buds under the name of "eyes," each of which eyes or buds is capable of independent growth when in a detached or isolated state. In its chemical composition, the potato shows a large proportion of starch with a very small quantity of proteid. The juice of the potato is acid, due to the presence of a certain amount of free citric acid with citrates of potassium, sodium, and calcium. In its dietetic value the potato is both a carbohydrate and an antiscorbutic. The starch grains of the potato (Fig. 30) are characterized by being large oyster-shaped granules with well-marked concentric rings, and a clear though small hilum at the narrow end. Potato starch is largely used for adulterating the more expensive farinaceous dietetic preparations; though cheaper, there is nothing to show that potato starch is less nutritive than other starches. Potatoes require to be cooked before being

eaten; this may be done by either steaming, boiling, baking, or frying. The heat coagulates the albuminous juices, and the absorbed water swells up and distends the starch grains. When these changes are complete, the potato is said to be mealy or floury; when these changes are only partially completed, and the starch cells imperfectly broken up and separated, the potato remains more or less firm, and is spoken of as being close, waxy, or watery. The potato plant is sometimes affected with a fungus—the *Phytophera infestans*—which causes the disease known as potato murrain. This can be readily detected by the microscope. The disease commences in the leaves of the plant, and thence extends to the stem and on to the tubers. On the surface of the latter, brown spots make their appearance, penetrate the potato, and eventually cause it to rot and decay.

FIG. 30.—Potato starch.

Arrowroots.—The arrowroots are obtained from various sources. Originally the term arrowroot was applied to the starch from the tuber or rhizome of the *Maranta arundinaceæ*, because that root was supposed to have the power of counteracting the effects of poisoned arrows. The term is now applied to a great variety of starches, but, strictly speaking, should be limited to those known in commerce as Canna, Curcuma, Maranta, and Tacca arrowroots. The root of the plants are dug up when about a year old, washed, and reduced to a pulp. This is repeatedly washed, passed through coarse sieves to separate the fibres, and the starch allowed to settle, which again is washed and dried. When finished ready for exportation, arrowroot is a white, tasteless, odourless substance, firm to the feel, and producing, on pressure, a slight crackling noise. Arrowroot, being a pure starch, has no dietetic value beyond that peculiar to this substance. It is chiefly used as a bland article of food for invalids, or, in an ordinary way, as blancmange, puddings, and biscuits.

Canna arrowroot is often called "Tous les mois," and is furnished by the *Canna edulis*, a native of the West Indies. Its starch grains are very like potato, but, on the whole, are larger and flatter with more definite striæ, or markings.

Maranta arrowroot, sometimes spoken of as Bermuda arrowroot (Fig. 31), is derived from the *Maranta arundinaceæ*, a plant which grows in Jamaica and Bermuda. Its granules are long and

ovoid; the rings, or striæ, are well-defined; while the hilum is in some circular, and in others a mere transverse line or slit.

Curcuma arrowroot is furnished from the *Curcuma angustifolia*, a species of turmeric plant. Its starch grains vary much in size, being, as a rule, flat and elongated. The striæ are not complete circles, and the hila, if present at all, are at the narrow end of the grain.

FIG. 31.—Arrowroot starch.

Tacca arrowroot is obtained from the *Tacca oceanica*, growing in Tahiti. Its granules are truncated, or wedge-shaped at one end. Their striation is indistinct, with a more or less circular hilum. All these starches of arrowroots readily form clear jellies on cooling after being heated with water. The true arrowroots are chiefly adulterated with potato, sago, and tapioca. What is called English arrowroot is merely potato starch.

Tapioca is a starch (Fig. 32) in the form of small granules, truncated at one end with large bases, indistinctly ringed, and with a more or less star-shaped hilum at the apex. It is prepared from the roots of the *Jatropha manihot*, or *Cassava*, growing in the Brazils.

FIG. 32.—Tapioca starch.

FIG. 33.—Sago starch.

Sago is another starch (Fig. 33) obtained from the interior of the *Sagus farinifera*, or sago palm, growing in Sumatra. The starch grains are very similar to those of tapioca, but larger.

Among the large class of succulent vegetables are such common articles of everyday life as cabbage, carrots, parsnips, turnips, beetroot, lettuce, etc. These can scarcely be regarded as foods, because the greater part of their carbohydrates exists in the indigestible form of cellulose, while their contained water amounts to about 90 per cent. Their general percentage composition may be put as—proteid, 2; fat, 0·5; carbohydrate, 7; salts, 1; water, 89·5.

All these vegetable foods are valuable for their antiscorbutic properties and for the salts which they contain, their absence from a diet leads to the production of scurvy.

The fruits are chiefly esteemed for their taste, though being, as they are, rich in water, vegetable acids, and salts, they are distinctly of service as preventatives of scurvy. Some fruits, such as grapes, contain sugar; while others, like dates and bananas, contain not only sugar, but starch. When eaten, fruit should not only be ripe, but quite free from decomposition. Some few, like dates and figs, can be dried, but the softer and more perishable varieties cannot be too fresh when eaten.

Lemons.—Owing to its great antiscorbutic powers, the lemon, or fruit of the *Citrus limonum*, is deserving of special notice. Its use as lemon-juice has practically eradicated scurvy from both the navy and mercantile marine. Lime- or lemon-juice, as met with in commerce, is chiefly prepared in Sicily or the West Indies. To preserve it, it is mixed with brandy or whisky in the proportion of about 1 oz. of spirit to 10 ozs. of juice, and olive oil is poured on the top to exclude air. Sugar, in the proportion of half its weight, is also added, to improve the taste. In the absence of fresh vegetables, 1 oz. of lemon- or lime-juice is the daily issue for the prevention of scurvy. Both lemon- and lime-juice contain large quantities of citric acid with some malic acid, proteid, and sugar. The citric acid, which is the most important constituent, averages from 7 to 8 per cent. Apart from their value as antiscorbutics, both lime- and lemon juice furnish agreeable and refreshing beverages; they allay thirst and sickness, and are of special value, too, as antidotes in poisoning by the alkalies. A good and pure lemon-juice should be clear, with an acid but not bitter taste, and possessed of a distinct aroma of the fruit. Many substitutes for lemon-juice are sold, the chief being a solution of citric acid in water flavoured with essence or oil of lemon. The chief adulterations are watering, and the additions of sulphuric and tartaric acids. The addition of water can be detected by the lowering of the specific gravity below 1030, and the diminution of the acidity below 30 grs. of citric acid per ounce. Sulphuric acid is probably the most important adulteration; it may be detected by filtering, and, after acidulation by hydrochloric acid, treating with chloride of barium, when the insoluble barium sulphate is thrown down, if sulphuric acid be present.

Preserved Foods.—For the preservation of meat, the chief methods are drying, freezing, salting, the injection of preservative solutions, and the exclusion of air, whether by covering it with an impervious coating or by hermetically sealing in tins. Meat preserved by *drying* is first cut into thin slices, and then exposed

to dry air, or to the smoke from a wood fire. In some countries, exposure to a hot sun is sufficient. The employment of extreme cold by *freezing* is now a very common mode of preserving meat, especially during importation from America and Australia. Meat can be preserved in ice for a long time, but unless the freezing had been commenced before rigor mortis set in, such preserved meat rapidly decomposes so soon as thawing is allowed. Experience shows that it is better to keep the meat at a temperature just short of freezing—say, 35° F.

Pickling by means of *salting* is an old and familiar means of preserving meat. During the process, the water of the meat is abstracted, and the salt acts as a preservative. Closely allied to this method is that of *injecting preservative solutions*, such as alum, or even common salt, and also by the application of preservatives to the surface, notably salt, sugar, boracic acid, salicylic acid, and charcoal. The *exclusion of air* is either secured by coating the meat with paraffin, or simply fat, and even by the simple device of plunging the joint into boiling water, so as to form an impervious layer of coagulated albumin on the surface. Probably the most frequent method based on air exclusion is that of hermetically sealing in tin cases. Various devices for securing this have been suggested, the chief being either a complete exclusion of the air by sealing *in vacuo*, or the exclusion of only a part of the air and removal of the oxygen of the remainder by sodium sulphite.

The chief objections to all these methods are, first, the danger depending upon possible original defects in the meat, and, secondly, the risks of decomposition and putrefaction if the preservation have been imperfectly carried out. In the case of tinned meats, not infrequently ill effects have followed their consumption, even when the original material has been above suspicion, and no sign of putrefaction has been present in the tin contents; the only unusual character being the presence of salts of tin, lead, or zinc in the meat and jelly, due possibly to the action of variable organic acids upon the solder or tin. Fortunately such events are rare. In the case of tinned or preserved peas an objectionable practice prevails of adding copper salts to give a green colour to the article. A special Committee appointed under the Sale of Foods and Drugs Act has reported that the use of copper salts in the so-called greening of preserved foods be prohibited.

As being closely allied to preserved forms of meat, allusion may here be made to the many *extracts of meat* now in the market. Some of them are pure stimulants, and not foods, while others are both. Among the former are Liebig's Extract, ordinary

beef-tea, and the soups. These are not proteid foods, for besides gelatine they contain only the merest traces of any other proteid; most of the myosin is coagulated during preparation, and left behind in the solid residue. These extracts are really salty foods, containing the sodium chloride from the blood and muscle liquid, the phosphates and potash from the muscle fibre itself, along with the extractives, such as kreatinin. They are essentially stimulants, restoring both mental and bodily activity, but in no sense can be regarded as true nitrogenous foods. On the other hand, there are some preparations which, besides being stimulants, are also proteid foods. These are made by drying more or less completely, partially digested meat, and then mixing this with glutin, starch, and concentrated milk. To this class belong such preparations, often given to invalids, as Carnrick's Beef Peptonoids, Darby's Fluid Meat, and others. It is of importance to understand the true value of these preparations, as too often their use is misapplied, owing to a misconception of their real nature.

Boiling it, and then tightly corking the vessel, is practically the simplest method for the preservation of milk; but, as a rule, this is but temporary. The same end is attained by adding antiseptics, such as salicylic acid, boric acid, or formalin, to the milk either before or after it has been boiled. The best forms, however, of preserved milk are the concentrated ones, such as the dried milk, or condensed milks with or without sugar. Those without sugar keep less well than those with sugar, once the tin in which they are sold is opened. The majority of condensed milks are made by evaporating down the original milk to a third or a quarter, and then adding sugar to it; this added sugar tends to make condensed milk rather fattening; but, on the whole, its nutritive value is below that of the fresh article, because, being made chiefly from skimmed or separated milk, it is poor in fats. This deficiency in fats, so constantly noticed in samples of condensed and preserved milks, renders them faulty articles of diet for young children, and indirectly accounts for the excessive prevalence of rickets among children reared upon these fatless milks. Strictly speaking, both "Koumiss" and "Kefir," which are fermented milks, are forms of preserved milk, both containing lactic and carbonic acid, with some alcohol. They are not much used, except as foods for the sick, in whom digestion is feeble.

Food Accessories.—This term has been proposed for the great group of condiments and beverages, because they include food stuffs which, though not absolutely necessary for existence, are still of much importance as aids to digestion and to the relishing of the more ordinary articles of diet. The Germans call them "means of enjoyment," as distinguished from the true foods or

"means of nourishment." They include substances varying from the simplest aromatic principles, such as one smells when meat is cooking, or condiments and spices, to the more complex alcoholic and non-alcoholic drinks which so largely enter into the daily dietaries of both civilized and uncivilized peoples. The general action of the food accessories seems to be to stimulate digestion, either directly by affecting the digestive organs, or indirectly through the central nervous system. The condiments are mainly added to food as flavouring agents; they include such articles as mustard, pepper, onions, cloves, nutmeg, cinnamon, salt, and vinegar. Excepting the two last, all these owe their value as food accessories to aromatic oils which they contain. These essential oils are all stimulants directly of the muscular movements of the digestive organs and of the secretion of their juices; but if taken in excess, easily induce gastric catarrh and exhaustion of the mucous lining of the stomach. The influence of common salt has already been discussed.

Vinegar is dilute acetic acid, more or less contaminated with gum, sugar, vegetable matter, etc. The varieties of vinegar met with in the market are wine vinegar, malt vinegar, and wood vinegar. The first two are produced by fermentation of alcohol, the process being one of oxidation from alcohol into aldehyde and then into acetic acid; the last by the destructive distillation of wood and subsequent separation of the acetic acid. The percentage of acetic acid ought not to be below 3 per cent., while in the best vinegars it may be as high as 6 per cent. Its specific gravity, if a wine vinegar, varies from 1015 to 1022; if a malt vinegar, from 1016 to 1019: anything below these figures is suggestive of dilution with water. The chief adulteration of vinegar is the addition of sulphuric acid in excess of that permitted by law, namely, 1 in 1000. If an excess be suspected, it must be determined by barium chloride. Occasionally, artificial vinegars are sold, being really nothing more than very dilute acetic acid coloured with caramel; they lack, however, the odour and bouquet of the volatile ethers which are so characteristic of the alcoholic fermentation products. The use of vinegar is not only that of an aid to food relishment, but, like other vegetable acids, helps to maintain the alkalinity of the blood, by conversion of the acetic acid into carbonates within the body. In doses of from half to an ounce daily, vinegar is an antiscorbutic, though inferior to lime- and lemon-juice. It is also an aid to digestion, particularly of some shell-fish, such as oysters and mussels. If taken in excess, especially when adulterated with sulphuric acid, vinegar tends to impair digestion.

The beverages included among food accessories may be

divided into those which contain no alcohol and those which do. The non-alcoholic beverages owe their action as food accessories chiefly to the alkaloids they contain; the more common of these beverages are tea, coffee, and cocoa; the two former have as their active principle the alkaloid theine or caffeine, while cocoa contains theobromine. Theine or caffeine is essentially a brain stimulant, exciting it to continued activity. If taken in excess, it produces not only an exhausted and disordered nervous system, but gives rise to acid dyspepsia, and considerable delay in the digestive process. Theobromine, though closely allied in its chemical nature to caffeine, has a slightly different physiological action, exerting its effects rather upon the muscular system, which it stimulates into activity, than upon the nervous system.

Tea consists of the dried leaves of a shrub called the *Camellia thea*, which grows in China, India, Ceylon, and Japan. As met with in everyday life, tea-leaves are curled, but they uncurl on being placed in hot water, and when so treated, are found to be ovate in shape, pointed, and with a margin toothed like a saw almost to the stalk. The arrangement of the veins in the tea-leaf is characteristic; the large veins do not reach to the border of the leaf, but turn in towards the midrib. The size of the leaves varies, and usually with them is some stalk. Practically all tea in the market is grown from the same species of shrub, the various names given as indicating different kinds are only trade names, and do not indicate really different varieties of tea-leaf so much as different qualities dependent upon mixing or blending, and on the age of the leaves, or on the soil on which the plant has been grown. In all cases, the leaf most highly valued is the small top leaf of the twig and the bud. Possibly these small leaves are neither finer in quality nor richer and better in flavour than the leaves next in succession, but being more tender and softer in structure, give better and more flavoured infusions. The various teas known under the trade names of Orange Pekoe, Pekoe, Suchong, Congou are all the same in respect of origin; they are picked at the same time from the same shrub. The bud and top leaf constitute Orange Pekoe, the two or three larger leaves growing on the same twig a little lower down are Suchong, and below that the leaves become Congou.

The most simple division of teas is into the green and the black; both are from the same plant, the only difference is their colour. Green tea is now little used, in consequence of the disrepute into which it fell as the result of the artificial colouring it received; but real green tea owes its colouration to being dried over wood fires when fresh. Black teas owe their colour to the leaves having been allowed to lie in heaps for twelve hours, during

which they undergo a process of fermentation, and are afterwards dried slowly over charcoal fires. "Brick tea" is made from the refuse, broken leaves and twigs, moulded into shapes. "Lie tea" consists of the dust of tea and other leaves made up by means of gum or starch into little masses, which are coloured or painted so as to resemble black or green tea; it is called "lie" tea because it is a false article and not tea at all. In selecting a fine tea, one should not be guided by any trade name, but determine, by pouring a little boiling water over the leaves and examining them, whether the leaf was a whole leaf and not a large leaf cut into small pieces. The larger the leaf, the weaker will be the infusion and the less the value. What are called "digestive" teas are varieties in which the tannin of the tea has been so altered by electrical treatment that it does not precipitate gelatin, and interferes but little with the digestion of starch.

The average percentage composition of tea may be expressed as follows:—

Water	8·0	
Theine	2·6	
Tannin	14·0	
Oil	0·4	
Extractives	15·0	
Insoluble organic matter	54·0	
Ash	6·0	Potash, iron, silica, alumina, magnesia.

Formerly, the chief adulteration of tea was by mixing with it other leaves, such as those of the sloe and willow, which have a superficial resemblance to tea-leaves. At the present time the chief adulteration of tea is the admixture of old and exhausted tea-leaves, while in the inferior kinds there is often clay, lime, or ferruginous sand. The total soluble matters obtainable from tea are a ready and convenient index of its quality: they are estimated by infusing a weighed quantity with an excess of distilled water, and evaporating this down to dryness; the amount of extract so obtained should be at least 30 per cent. If the sample contain many exhausted leaves, the amount of extract obtained will be, of course, less than this. The ash obtained by burning a given quantity of the tea sample should, in a good specimen, be at least 5 to 6 per cent., and not more than 8 per cent.; and of this at least 3 per cent. or half should be soluble. The precise estimation of the theine and tannin are matters of some difficulty, but are not certain data upon which to judge the purity of any particular sample.

The most essential points in making good tea of the finest quality and with the least waste are to have actually boiling water,

and tea-leaves so crushed and subdivided that the largest possible surface is rapidly exposed to the boiling water in infusing it. This explains why the best tea-infusion in the world is that made by the Japanese from their carefully prepared "tea-powder," which is made by crushing to a fine powder certain well-selected leaves. The tea bricks of China probably owe their superiority to being well-crushed leaves of good quality. The use of tea-powder, obtainable in Europe, is handicapped by its liability to adulteration, its uncertain mixture, and difficulties in its preparation. Possibly these disadvantages may be overcome by a more extended employment of tea tabloids, made by the compression of carefully selected and finely ground teas from Japan, India, and Ceylon.

The excessive drinking of tea is bad, especially when fasting. Tea is not a food, and should not be taken as such; but if used in moderation, it undoubtedly serves a useful purpose among our daily wants. It is essentially a stimulant of the brain and nervous system, producing no subsequent depression; but if taken in excess induces indigestion, loss of appetite, and constipation: in some persons, these bad effects are produced even when only small quantities are consumed.

Coffee is the seed, or berry, of the *Caffea Arabica*, a plant growing in most parts of the tropics, but chiefly in Arabia, Abyssinia, Ceylon, and the West Indies. After the seeds have been roasted to a chocolate brown, they are ground to a powder in a mill, and then used in the form of a decoction or infusion. The percentage composition of unroasted coffee may be expressed as follows:—

Water	11·23
Nitrogenous matter	12·07
Caffeine	1·21
Fat	12·27
Sugar or dextrin	8·55
Tannin	32·79
Cellulose	18·17
Salts	3·71

The chief properties of coffee depend upon an aromatic oil and an alkaloidal body called caffeine. Caffeine itself is a nitrogenous crystalline alkaloid identical with theine; in the roasting of coffee this body is not destroyed, but dissociated, as it were, from its previously existing combination with tannin. During the same process the sugar and dextrin are changed into caramel, and the gas and water of the berry are driven off.

The adulterations of coffee are chiefly chicory, but at times dates, beans, maize, and acorns have been added. Chicory is a

legal addition to coffee, provided such admixture be stated, no limit being fixed as to their relative proportions; as a rule, it amounts to about 30 per cent. The addition of chicory to coffee is considered by most people to add to its flavour. It is probable that much of the present decadence of coffee drinking is due to the excessive addition of chicory, whereby the resulting infusion is wanting in the desired alkaloid caffeine. To make good coffee the berry must be freshly roasted. Good drinkable coffee requires as much as an ounce of recently roasted and ground coffee to each large cup, the result of which means that the cost of a cup of good coffee, including milk and sugar, is about twopence. The prevalent custom of making coffee in this country is to use barely an ounce to two pints of water, the resulting infusion being more or less mawkish, tasteless, and wanting in stimulating properties. Chicory itself is the dried and powdered root of a plant called the *Cichorium intybus*. In composition it differs much from coffee, containing no caffeine, less fat, but more sugar. It may be readily distinguished from coffee by the fact that when thrown into water it rapidly sinks and colours the liquid brown, while coffee floats and does not yield any colour. If adulterations are present in the form of the starch grains from various cereals, both a microscopical examination and the blue reaction with a dilute solution of iodine will betray them.

A more exact estimation of chicory in mixtures of coffee and chicory can be made by calculating the percentage of extract yielded by the sample after infusion in boiling water. Pure chicory gives a mean percentage extract of 70; while pure coffee gives a remarkably constant percentage extract of 24. Consequently we have—

$$\text{Percentage of coffee in sample} = \frac{100 \times (70 - \text{percentage of extract})}{70 - 24}$$

Coffee, like tea, appears to act decidedly upon the nervous system, which it stimulates, causing wakefulness and increased brain action. In some people it has an aperient action by stimulating the muscular coats of the intestines.

Cocoa is the roasted seed of the *Theobroma cacao*, growing chiefly in the West Indies. Cocoa nibs are the seeds or beans roughly broken; flake cocoa is the same completely ground and crushed; soluble cocoa is the same freed from cellulose; while prepared cocoa is the same after half or more of its contained oil or fat has been removed, and in most cases starch and sugar added. The percentage composition of cocoa beans may be said to be as follows :—

Water	6·0
Theobromine	1·5
Fat	50·0
Starch	10·0
Salts	3·6
Gum	8·0
Cellulose	20·9

Theobromine closely resembles caffeine, not only in its nature, but in its action. The adulteration of cocoa is chiefly in the direction of the addition of sugar and starch, which the microscope will detect; while, by some, the removal of the fat, so as to reduce it below 20 per cent., is regarded as an adulteration. Apart from cocoa by nature containing nitrogenous and fatty matter, in its commercial forms it contains so much starch and sugar that it is rightly regarded to some extent not only as a proteid and fatty food, but also a carbohydrate one. Cocoa differs much from both tea and coffee in having but little stimulant action, but it does possess some nutritive value, and, as such, may in a limited sense be regarded as a food.

Chocolate is a preparation of cocoa, from which the greater part of the fat has been removed, and which, after being mixed with sugar and various flavouring substances, is made into a paste with water, and then pressed in moulds.

Aerated Waters.—In addition to the large number of natural waters, rich in carbon dioxide, there are many artificial aerated waters which have come into general use of late years. The peculiar feature of them all is that they are prepared by forcing carbon dioxide into ordinary water, and adding to it either some saline or a flavouring agent. Much of what is known and largely sold as "soda water" really contains no soda at all, but is merely an ordinary water highly aerated and charged with carbon dioxide. If the gas, naturally present in the water, is not previously thoroughly expelled, the carbon dioxide is imperfectly dissolved, and when the bottle is opened, tends to froth and escape violently. The chief sources of danger in these beverages lie in the possible employment of originally impure water; the making of the carbon dioxide from impure materials; the presence of either lead, copper, or tin, as the result of imperfect washing of the gas, or derived from the plant used in the manufacture. These dangers can only be obviated by the exercise of care in the selection of the water and materials used. Fortunately carbon dioxide, under pressure, is a poison to the majority of micro-organisms present in water. This is a fact which may in great measure explain the remarkable immunity from filth diseases, such as enteric fever and cholera, which attends the habitual use of highly aerated waters in place of the ordinary supplies. It would, however, be

desirable if legislation could make it illegal to use any water but that possessing all the qualities of an unobjectionable drinking water for the making of aerated beverages. The presence of any deleterious metals is uncommon in these drinks, except those made in inferior and faulty machines. The aerated waters stored in bottles with patent stoppers of porcelain, glass, and vulcanite are, of course, the most generally free from any of the hurtful metals. It is questionable whether any real danger exists to health under this heading.

Alcoholic Beverages.—Among the alcoholic beverages, the chief are beer, wine, and spirits; these all owe their action as food accessories partly to the alcohol and partly to certain aromatic principles and substances which they contain. The alcoholic beverages are sometimes called fermented liquors, because the alcohol contained in them is the result of a process called fermentation set up in either the natural sugars which we extract from fruits, stalks, or roots of certain plants, such as the grape, the sugar-cane, and the beetroot, or in the secondary sugars which we prepare by art from potatoes, cereal grains, malt, and the starches generally.

If we take a natural sugar, such as grape-sugar present in the fruit of the vine, dissolve it in water, and add a little yeast to it, the solution quickly begins to ferment. During this fermentation the sugar is split up into alcohol and carbon dioxide. The former remains in the liquid, while the carbon dioxide escapes as a gas in bubbles into the air. The yeast which brings about this remarkable change is in reality a microscopical plant, made up of oval cells about $\frac{1}{2000}$ of an inch in diameter, filled with granular matter. The scientific name for yeast is *Torula cerevisiæ*. It is by virtue of this fermentation of grape juice, as we shall learn later, that wine and brandy are made. If instead of grape-sugar, we take common cane-sugar, dissolve it in water, and mix with yeast, fermentation is set up in a similar way; excepting that the cane-sugar is first changed into fruit or grape-sugar by the action of the yeast, and then the grape-sugar is split up into alcohol and carbon dioxide. These changes go on whether the sugar be exposed to the air or not. If now, instead of taking either grape-sugar or cane-sugar, we take some ordinary starch, boil it in a dilute solution of almost any acid, particularly 1 per cent. of sulphuric acid, the starch is converted into a sweet gum-like body called dextrin, and subsequently into a kind of sugar called maltose, which closely resembles in sweetness, chemical composition, and general properties that of the grape. If yeast be now added to this altered starch, the same fermentation and production of alcohol takes place. It is from potato starch treated in this

manner that large quantities of spirit, known as potato brandy, are manufactured in various countries.

In a previous chapter it has been explained that the cereal grains consist essentially of two principal substances—namely, starch and a nitrogenous body of the nature of a globulin or albumose. These evidently are intended by nature to afford the first food of the young plant as it grows from the grain; but in their natural state these are insufficiently soluble to supply the wants of the growing germ. Under the influence of moisture, as when a grain of wheat sprouts, a ferment in the form of a soluble white substance called *diastase* is formed in the grain, which so converts the nitrogenous elements of the seed as to make it usable by the young plant, and for the same purpose also changes the insoluble starch into soluble starch, dextrin, maltose, and glucose or grape-sugar. This is why sprouted corn always has a sweet taste. The maltster, brewer, and distiller avail themselves of this natural change in the constituents of sprouting grain, and on a large scale call into action the chemical influence of this unorganized ferment known as diastase.

In the manufacture of all fermented drinks, therefore, two distinct chemical processes are involved; there is first the change of the starch into sugar, and secondly the change of the sugar into alcohol and carbon dioxide. This latter we know is brought about by fermentation through the medium of yeast, while the former may be secured by the artificial conversion, by means of sulphuric or other acid, of potato or other starch into sugar; or the grain may be manufactured into malt and the remarkable influence of diastase called into play.

The essential element in all fermented drinks, no matter how made, is alcohol, which is a neutral compound of oxygen, carbon, and hydrogen, having the chemical formula of C_2H_6O. When quite pure and free from water, alcohol is termed *absolute alcohol*, having a specific gravity at 60° F. of 0·79381; when mixed with 16 per cent. of water, it is called *rectified spirit*, and when mixed with 56·8 per cent., volume in volume of water, it constitutes *proof spirit*. Proof spirit is a term constantly in use for excise purposes, signifying a dilute spirit of definite strength. If expressed as volume in volume, proof spirit contains 56·8 per cent. of absolute alcohol; if as weight in weight, 49·25 per cent.; if as weight in volume, 45·4 per cent.; the remainder in each case being distilled water. The ratio of alcohol to proof spirit in each of these cases being for volume in volume as 1 is to 1·76; for weight in weight as 1 is to 2·03, and for weight in volume as 1 is to 2·21. We can, therefore, if in any case the percentage of contained alcohol be known, calculate the amount

of proof spirit present by multiplying the given percentage of alcohol by any of the foregoing ratios.

Spirits which are weaker than proof are described as being *under proof;* when stronger than proof as being *over proof.* Thus, say a sample of whisky is found to contain 70 per cent., volume in volume, of alcohol; then $70 \times 1{\cdot}76 = 123{\cdot}2$, and the excess of this product over 100 or 23·2 gives the number of degrees over proof which the sample has. If, on the other hand, it contain but 24 per cent. of alcohol, volume in volume, then $24 \times 1{\cdot}76 = 42{\cdot}24$, and by just so much as this figure is greater or less than 100 is the sample degrees over or under proof, that being, in this case, just 57·76° under proof. Conversely, if the degree of strength of any spirit over or under proof be known, the percentage of alcohol present can be calculated either as volume in volume, weight in weight, or weight in volume. Thus, say a sample of brandy be x degrees over proof; then $\frac{100 + x}{1{\cdot}76}$ gives the percentage, volume in volume, of alcohol which it contains. If it be x degrees under proof, then $\frac{100 - x}{1{\cdot}76}$ gives the percentage, volume in volume, again of alcohol.

Nutritive Use of Alcohol.—The use of alcohol by man is of very ancient origin, and owing to the ease with which alcohol is produced by fermentation from sugars and starches, its early discovery and almost universal use throughout the world are not at all remarkable. In attempting to understand the physiological action of alcohol, one must bear in mind that there is a distinction between the effects of alcohol taken in dietetic doses and when taken in excess, and too, that the physiological action of pure alcohol is not quite the same as that of many alcoholic beverages, because many of these contain other bodies besides alcohol, and which have a distinct action of their own. Moreover, it must not be forgotten that what is a dietetic dose for one person is an excess for another. As based upon the experiments of Parkes, Anstie, and others, the amount of alcohol which can be taken daily by the average individual without doing harm is between one and two fluid ounces. This is contained in about two ounces of ordinary spirit, such as brandy or whisky, and in half a pint of the light wines, such as clarets and Burgundies, or in about a pint and a half of the ordinary beers and ales.

It is still a matter of dispute as to how alcohol is eliminated from the body, and whether any of it is destroyed in the tissues. The probable truth is that alcohol is oxidized in the body, the products being excreted in the urine. In small doses, alcohol

stimulates the nervous system, reddens the lining membrane of the stomach, increasing the secretion of the gastric juice, and thus may in very small doses promote the appetite. When carried into the circulation, it increases the heart's action, and at the same time causes the smaller blood-vessels or capillaries to dilate. It is an unsettled question as to how far alcohol lowers the body temperature in health, but it is beyond question that it tends to lower the natural resisting power of the body against cold, and is in consequence unsuited for those exposed to great degrees of cold as in the Arctic regions. If taken too often, even in small doses, or taken in any large quantity at one time, alcohol instead of stimulating the nervous system actually depresses and paralyzes it, as evidenced by intoxication. In these circumstances the perception power of the brain is depressed or paralyzed, correct judgment is impossible, while speech is disordered and the emotions out of all control. If repeatedly taken to excess, alcohol delays digestion, causes catarrh of the stomach and bowels, accompanied by such degenerated conditions of both the liver and kidneys as to result in death. It is beyond question that, when taken in sufficient quantities to produce these effects upon the brain and nervous system, alcohol causes an immensity of harm; the physical, moral, and social evils of intemperance are only too familiar to us all. But how far alcohol is beneficial or not when taken in small or dietetic doses is still a matter of controversy between the teetotalers and those who advocate moderation. Of one thing there can be no doubt, as all are agreed upon it, namely, that a person can do quite as hard if not harder work without alcohol than with it; the experience of wars and expeditions in all climates, where abstinence was either enforced by order or by circumstances, shows that soldiers endure more fatigue, are healthier, and fight better without alcoholic stimulants than with them. On the other hand, it must be borne in mind that in ordinary life to many the cares and worries of business and existence are such that to them, after the labours of the day, a moderate amount of alcohol in some form or other is not only an advantage but almost a necessity. To the old and feeble, the use of alcohol is not less valuable. In all cases, however, it should be remembered that alcohol should never be taken during working hours with the idea that the body and brain are likely to do more work after it than before; the only time when it can be advantageously used is after the day's work is done; so taken, its influence is often to check tissue change and waste, to soothe and stimulate an exhausted brain with a removal of the sense of fatigue, and to promote digestion. Alcohol should never be taken fasting; its

best effects are secured when taken with food, and at no meal more so than at the late dinner or supper.

Beer.—The usual definition of beer is, that it is a fermented infusion of malt flavoured with hops. This, however, is not quite correct at the present day, as sugar largely takes the place of malt, and other vegetable bitters that of hops; so that probably a more accurate definition would be, to call it a fermented saccharine infusion to which has been added any wholesome bitter. Formerly the substitution of quassia, gentian, calumba, or any other bitter in place of hops was illegal, but now it is not the case, with the result that all kinds of bitters may be used provided they are wholesome. As a matter of fact, however, in the best beers even now, the only bitter used is hops.

Modern beers may be divided into two great groups, namely, the non-malt beers and the malt beers. What are called non-malt beers are those made by a yeast fermentation of an infusion of sugar, mainly derived from starch chemically or artificially converted, as by the action of sulphuric acid. Malt beers are the result of a similar yeast fermentation of an infusion of sugar, only in this case the sugar is derived from the natural conversion of grain starch by means of germination or malting. In both instances, the resultant liquor is an alcoholic one, in which a portion of the alcohol becomes transformed into aldehyd, and subsequently by a further oxidation changed into acetic acid.

The actual preparation of malt and the subsequent brewing of beer is easy to understand. The maltster first soaks his barley in a cistern for some fifty hours; he then transfers it to the "couch," and twenty hours later spreads it out on floors in a malting. Here he leaves it for ten or fourteen days, during which time germination takes place, and the grain sprouts. After this sprouting has taken place sufficiently, all germination action is arrested by drying the grain over a kiln. It is now malt, and if tasted is distinctly sweet, owing to the conversion of the grain starch into sugar by the action of the diastase ferment, as explained a few pages previously. After the dried malt has been sifted or screened so as to break off all the sproutings, it passes into the hands of the brewer, who, after crushing it, places it in his mash tub with water warmed to about 160° F. This water completes the transformation of the starch into grape-sugar and dissolves it, causing the resulting liquor, or *wort* as it is called, to have a decidedly sweet taste. In the case of a brewer using chemically converted starch or a mixture of it with malt, a similar treatment with warm water would be followed by the production of a sweet liquor or wort. When

the conversion of the starch into sugar is sufficiently complete, all chance of further conversion is stopped by boiling the wort, which also acts in coagulating the albumin which the water has dissolved out of the grain; advantage is also taken of the boiling to add hops, which aid further in clearing the wort by coagulating the remaining albuminous matter, besides imparting to it their characteristic bitterness. Both the length of the boiling and the quantity of hops added vary according to the richness of the wort in sugar, and with the quality of beer it is intended to make.

The next step in brewing is to run off the boiled liquid into shallow vessels, in which they are cooled to the best temperature for fermentation. If "top" yeast is going to be used, this temperature is 60° F., but if what is called "bottom" or sedimentary yeast, as used in Bavaria, a much lower temperature is preferable. When at the required heat, the liquid is run into the fermenting tun and a sufficient quantity of yeast added. It is usual to use a yeast obtained from a kind of beer different from that which it is proposed to make; the whole is allowed to ferment slowly for six or eight days. During this time, the sugar splits up into alcohol, which remains in the beer, and into carbon dioxide, which, for the most part, escapes into the air. The most essential points in brewing are the facts that the quantity of yeast to be added and the temperature at which fermentation is allowed to take place, vary with different kinds of beer; also that yeast works better when transferred from one kind of beer to another; and that the fermentation must be so regulated that the whole of the sugar contained in the wort is not transformed into alcohol, as if it is all so transformed the beer has no keeping power—that is, it would turn sour in the casks. This turning sour is due mainly to the passage of the alcohol into aldehyd and the subsequent oxidation of this into acetic acid.

There are many varieties of ales and beers, the chief being: *Pale* and *Mild Ales*, made from the finest dried malt and the best hops; the mild ale is usually sweeter, stronger, and less bitter than the pale. *Porter* is nothing more than a weak mild ale, coloured and flavoured with roasted malt. *Stout* is a richer and stronger kind of porter. The *German Beers* are fermented by means of sedimentary yeast as distinguished from the surface yeast used in England. Their fermentation is carried on at a lower temperature than in the case of British beers. They contain also less alcohol than the English, but are richer in carbon dioxide, and keep better. *Lager* and *Bock* beer is made from a stronger wort, and is proportionately richer in alcohol and malt extract. The *Belgian beers* are made with unmalted wheat and

barley; they take long periods to ferment, doing so spontaneously, no yeast being added; as a rule, they are hard from the presence of much acid. *Bottled beers* are all bottled while fermentation is going on, and owe their sparkling and frothing to the excess of carbon dioxide in them.

The chief constituents of ales, stouts, and porters are—alcohol, dextrin, sugar, hop resin or oil, glutin, acetic and lactic acids, carbon dioxide, mineral ash, and water. The alcohol in beer varies from 1 to 10 per cent. in volume. The free acidity which arises chiefly from acetic, lactic, and malic acids, if expressed as acetic acid, ranges from 15 to 40 grs. per pint. The malt extract, which consists mainly of sugar, dextrin, and cellulose, varies from 4 to 15 per cent. Some beers have been known to be the cause of arsenical poisoning, as in the notorious epidemic in Lancashire in 1900. This arose from the employment of an arsenically tainted sulphuric acid for the manufacture of the sugar subsequently used for brewing the beer. Such a sequence of events is fortunately rare, but it brings into prominence the great need for scrupulous purity in all ingredients used in the preparation of foods and drinks.

Regarded as a food, the nutritive value of beer is small though, of course, higher than other alcoholic drinks, owing to the large amount of maltose, dextrin, and other saccharine substances which it contains in the form of malt extract. In the main, its dietetic effects are those of alcohol, modified by the associated action of other ingredients. Beer appears to have some action peculiarly its own; this is generally attributed to *lupulin*, which is the active principle in hops. On some people, beer acts as a depressant, and, if taken in excess, it undoubtedle is a soporific or stupor producer. Beer also seems to exercisy slight but continuous interference with tissue change, with a tendency to fatten and produce gout and rheumatism. When drunk to any excess, beer appears to have a retarding effect upon digestion.

In its general characters a good beer should be transparent with a red-brown colour, and possessed of a semi-vinous flavour. Formerly, many hurtful ingredients were added to beer as adulterants, but in the present day, practically the only adulterations are water with occasionally salt or alum. Salt is usually present in small amounts in the best beers, being derived from the water and other ingredients in making; but if present in excess of 10 grs. per gallon amounts to an adulteration. Alum is sometimes added to beer combined with salt, and sulphate of iron or even sugar in order to raise the density and give a "head" after dilution with water. Such beer soon undergoes secondary

fermentation, and becomes sour, heady, and unwholesome. The quality of ale is most conveniently estimated by a determination of the amounts of its acidity and its contained alcohol. For determining the acidity of beer, we need an alkaline solution of known strength, of which 1 c.c. is equal to 6 mgms. of acetic acid. The amount of this solution required to exactly neutralize a given quantity of beer is determined and expressed as acid in grains per pint. This, representing the *total* acidity of the beer, rarely exceeds 26 grs. per pint, more commonly is about 16 grs. per pint.

To determine the amount of contained alcohol and the original gravity of a beer, the following procedure is necessary: By means of a gravity bottle determine the specific gravity of the sample at 60° F. Next evaporate 200 c.c. of the beer down to about one-third, allow to cool, measure, and re-make up to its original volume with distilled water, and then determine the specific gravity of this de-alcoholized beer at 60° F. Deduct the gravity obtained before evaporation from that after it, and take the difference from 1000. Having obtained this figure, refer to the accompanying table of degrees of specific gravities, and read off opposite the number obtained the percentage of alcohol present.

Specific gravity at 60° F.	Volumes per cent. of alcohol.	Specific gravity at 60° F.	Volumes per cent. of alcohol.	Specific gravity at 60° F.	Volumes per cent. of alcohol.
1000·0	0·00	990·2	7·00	979·0	17·00
999·9	0·05	989·0	8·00	978·0	18·00
999·8	0·15	987·8	9·00	977·0	19·00
999·1	0·55	986·6	10·00	976·0	20·00
998·5	1·00	985·4	11·00	970·9	25·00
997·0	2·00	984·3	12·00	965·4	30·00
995·6	3·00	983·2	13·00	959·2	35·00
994·2	4·00	982·1	14·00	951·9	40·00
992·9	5·00	981·1	15·00		
991·5	6·00	980·0	16·00		

From the same data, practically, the gravity of the original wort from which the beer was brewed can be calculated. Taking the difference between the two gravities, obtained respectively before and after de-alcoholization, we obtain a figure or number which is called the approximate spirit indication. Next determine the acidity of the beer as a percentage of acetic acid: from the following acidity table, read off the spirit indication corresponding to this acidity. Add this figure to that of the approximate spirit indication, and we get what is called the true spirit indication.

TABLE FOR ASCERTAINING THE SPIRIT VALUE OF ACTIVE ACID IN BEER.

Percentage of acetic	Corresponding degrees of spirit indication.									
		0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
0·0		0·02	0·04	0·06	0·07	0·08	0·09	0·11	0·12	0·13
0·1	0·14	0·15	0·17	0·18	0·19	0·21	0·22	0·23	0·24	0·26
0·2	0·27	0·28	0·29	0·31	0·32	0·33	0·34	0·35	0·37	0·38
0·3	0·39	0·40	0·42	0·43	0·44	0·46	0·47	0·48	0·49	0·51
0·4	0·52	0·53	0·55	0·56	0·57	0·59	0·60	0·61	0·62	0·64
0·5	0·65	0·66	0·67	0·69	0·70	0·71	0·72	0·73	0·75	0·76
0·6	0·77	0·78	0·80	0·81	0·82	0·84	0·85	0·86	0·87	0·89

From the annexed table (pp. 200 and 201) read off the gravity (representing sugary extract which has fermented or become converted into alcohol and acid) corresponding to this spirit indication. If this figure be now added to the gravity given by the de-alcoholized beer (representing unfermented sugary extract), we get then the probable original gravity of the wort from which the beer was brewed.

Example. Say a beer sample has yielded 0·04 per cent. of acetic acid, and that the first and second gravities were respectively 1016·47 and 1023·36; the difference between these gravities is clearly 6·89, and this taken from 1000 gives 993·11 corresponding in the alcohol table to 4·84 per cent. of contained alcohol. The original gravity of the wort would be calculated as follows: The difference between the two gravities taken before and after de-alcoholization we know to be 6·89, while the percentage of acetic acid is 0·04, corresponding by the acidity table to a spirit indication of 0·07. Then 6·89 *plus* 0·07 gives a true spirit indication of 6·96, which, by a reference to the other table, is equivalent to 28·6 degrees of gravity lost by fermentation. Then, as the second gravity, or that obtained after de-alcoholization and representing unfermented extract, is 1023·36, by adding this to 28·6 we get 1051·96 as the probable original gravity of the wort from which the actual beer sample was brewed.

Some idea as to the solids or amount of extract per cent. in a beer can be obtained if, after taking the specific gravity after de-alcoholization, the excess of gravity over 1000 be divided by 4; this gives an approximate conclusion as to the body of the beer; the more extract, the greater is the body of the ale. In the example given above, the extract would be calculated as being 23·36 divided by 4 or 5·75 per cent.

Wine.—The term wine is held to mean "the fermented juice of the grape with such additions only as are essential to the stability or keeping quality of the wine." This definition admits as wines those beverages which, made from grape juice, require to preserve them the addition of spirit, as in the case with some

TABLE SHOWING DEGREES OF SPIRIT INDICATION WITH CORRESPONDING DEGREES OF GRAVITY LOST.

Spirit indication. Degrees and tenths.	Hundredths of a degree. 0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
4·0	15·10	15·14	15·18	15·22	15·26	15·30	15·34	15·38	15·42	15·46
·1	15·50	15·55	15·60	15·65	15·70	15·75	15·80	15·85	15·90	15·95
·2	16·00	16·04	16·08	16·12	16·16	16·20	16·24	16·28	16·32	16·36
·3	16·40	16·44	16·48	16·52	16·56	16·60	16·64	16·68	16·72	16·76
·4	16·80	16·85	16·90	16·95	17·00	17·05	17·10	17·15	17·20	17·25
·5	17·30	17·34	17·38	17·42	17·46	17·50	17·54	17·58	17·62	17·66
·6	17·70	17·75	17·80	17·85	17·90	17·95	18·00	18·05	18·10	18·15
·7	18·20	18·24	18·28	18·32	18·36	18·40	18·44	18·48	18·52	18·56
·8	18·60	18·65	18·70	18·75	18·80	18·85	18·90	18·95	19·00	19·05
·9	19·10	19·14	19·18	19·22	19·26	19·30	19·34	19·38	19·42	19·46
5·0	19·50	19·54	19·58	19·62	19·66	19·70	19·74	19·78	19·82	19·86
·1	19·90	19·95	20·00	20·05	20·10	20·15	20·20	20·25	20·30	20·35
·2	20·40	20·45	20·50	20·55	20·60	20·65	20·70	20·75	20·80	20·85
·3	20·90	20·94	20·98	21·02	21·06	21·10	21·14	21·18	21·22	21·26
·4	21·30	21·35	21·40	21·45	21·50	21·55	21·60	21·65	21·70	21·75
·5	21·80	21·84	21·88	21·92	21·96	22·00	22·04	22·08	22·12	22·16
·6	22·20	22·25	22·30	22·35	22·40	22·45	22·50	22·55	22·60	22·65
·7	22·70	22·74	22·78	22·82	22·86	22·90	22·94	22·98	23·02	23·06
·8	23·10	23·15	23·20	23·25	23·30	23·35	23·40	23·45	23·50	23·55
·9	23·60	23·65	23·70	23·75	23·80	23·85	23·90	23·95	24·00	24·05
6·0	24·10	24·15	24·20	24·25	24·30	24·35	24·40	24·45	24·50	24·55
·1	24·60	24·65	24·68	24·72	24·76	24·80	24·84	24·88	24·92	24·96
·2	25·00	25·05	25·10	25·15	25·20	25·25	25·30	25·35	25·40	25·45
·3	25·50	25·55	25·60	25·65	25·70	25·75	25·80	25·85	25·90	25·95
·4	26·00	26·04	26·08	26·12	26·16	26·20	26·24	26·28	26·32	26·36
·5	26·40	26·45	26·50	26·55	26·60	26·65	26·70	26·75	26·80	26·85
·6	26·90	26·95	27·00	27·05	27·10	27·15	27·20	27·25	27·30	27·35
·7	27·40	27·44	27·48	27·52	27·56	27·60	27·64	27·68	27·72	27·76
·8	27·80	27·85	27·90	27·95	28·00	28·05	28·10	28·15	28·20	28·25
·9	28·30	28·35	28·40	28·45	28·50	28·55	28·60	28·65	28·70	28·75

TABLE SHOWING DEGREES OF SPIRIT INDICATION WITH CORRESPONDING DEGREES OF GRAVITY LOST (*continued*).

Spirit indication — Degrees and tenths	Hundredths of a degree. 0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
7·0	28·80	28·84	28·88	28·92	28·96	29·00	29·04	29·08	29·12	29·16
·1	29·20	29·25	29·30	29·35	29·40	29·45	29·50	29·55	29·60	29·65
·2	29·70	29·75	29·80	29·85	29·90	29·95	30·00	30·05	30·10	30·15
·3	30·20	30·25	30·30	30·35	30·40	30·45	30·50	30·55	30·60	30·65
·4	30·70	30·75	30·80	30·85	30·90	30·95	31·00	31·05	31·10	31·15
·5	31·20	31·25	31·30	31·35	31·40	31·45	31·50	31·55	31·60	31·65
·6	31·70	31·75	31·80	31·85	31·90	31·95	32·00	32·05	32·10	32·15
·7	32·20	32·25	32·30	32·35	32·40	32·45	32·50	32·55	32·60	32·65
·8	32·70	32·75	32·80	32·85	32·90	32·95	33·00	33·05	33·10	33·15
·9	33·20	33·25	33·30	33·35	33·40	33·45	33·50	33·55	33·60	33·65
8·0	33·70	33·76	33·82	33·88	33·94	34·00	34·06	34·12	34·18	34·24
·1	34·30	34·35	34·40	34·45	34·50	34·55	34·60	34·65	34·70	34·75
·2	34·80	34·86	34·92	34·98	35·05	35·10	35·16	35·22	33·28	35·34
·3	35·40	35·45	35·50	35·55	35·60	35·65	35·70	35·75	35·80	35·85
·4	35·90	35·96	36·02	36·08	36·14	36·20	36·26	36·32	36·38	36·44
·5	36·50	36·55	36·60	36·65	36·70	36·75	36·80	36·85	36·90	36·95
·6	37·00	37·05	37·10	37·15	37·20	37·25	37·30	37·35	37·40	37·45
·7	37·50	37·55	37·60	37·65	37·70	37·75	37·80	37·85	37·90	37·95
·8	38·00	38·06	38·12	38·18	38·24	38·30	38·36	38·42	38·48	38·54
·9	38·60	38·65	38·70	38·75	38·80	38·85	38·90	38·95	39·00	39·05
9·0	39·10	39·16	39·22	39·28	39·34	39·40	39·46	39·52	39·58	39·64
·1	39·70	39·75	39·80	39·85	39·90	39·95	40·00	40·05	40·10	40·15
·2	40·20	40·25	40·30	40·35	40·40	40·45	40·50	40·55	40·60	40·65
·3	40·70	40·75	40·80	40·85	40·90	40·95	41·00	41·05	41·10	41·15
·4	41·20	41·25	41·30	41·35	41·40	41·45	41·50	41·55	41·60	41·65
·5	41·70	41·75	41·80	41·85	41·90	41·95	42·00	42·05	42·10	42·15
·6	42·20	42·25	42·30	42·35	42·40	42·45	42·50	42·55	42·60	42·65
·7	42·70	42·75	42·80	42·85	42·90	42·95	43·00	43·05	43·10	43·15
·8	43·20	43·25	43·30	43·35	43·40	43·45	43·50	43·55	43·60	43·65
·9	43·70	43·75	43·80	43·85	43·90	43·95	44·00	44·05	44·10	44·15

wines from Spain and Portugal; but it excludes the so-called British wines, which are not made from the juice of the grape at all, and those wines from other countries, which are fortified with spirit when they require no such addition.

When the sugary juice of a fruit, such as the grape, is left to itself at a moderate temperature, fermentation takes place from the influence and action of germs present in the air; this process differing very much from that in the making of beer, when the starchy or sugary infusion or wort is boiled, and then yeast added to make it ferment. During the fermentation of the fruit juice, a part or whole of the sugar is converted into alcohol. Various ethers, which give the characteristic flavour or bouquet to wine, are formed, as well as acetic, malic, succinic, and other acids. The essential acid of wine is tartaric acid; much of this crystallizes in the casks as cream of tartar or tartrate of potash. The newer wines contain aldehyd, which is very intoxicating; later on this gets oxidized into acetic acid, and if exposed to the air long enough, all the alcohol in a wine will be converted into this acid so as to practically become ordinary wine vinegar. Much of the colour, taste, and character of wines depend upon how far they are made from the grape juice only, or how much this is mixed with the seeds and skins of the fruit. The seeds are rich in tannin and a bitter principle, while the skins yield a colouring matter, some flavouring principle, and tannin.

With regard to the amount of alcohol which a wine contains there is no constancy. All wines can be divided according to their alcoholic strength into two classes: the natural wines, containing from 6 to 13 per cent. by weight of alcohol; and the fortified wines, containing from 12 to 22 per cent. by weight of alcohol. The limit of alcoholic distinction between these two great classes of wine will be more readily understood if it be borne in mind that during the fermentation of any sugary liquid or mass, that process at once ceases when the alcohol formed reaches 14 per cent., so that any excess of alcohol over that amount must, of necessity, have been added artificially. The ports and sherries are all largely fortified with added alcohol; while many of the inferior clarets and champagnes are subject to very similar additions. The strongly alcoholic and fortified wines are slow to undergo change, hence keep well; but the lighter and natural wines deteriorate rapidly when exposed to air.

Like the alcohol, the sugar in wine varies much, being for the most part in the form of fruit sugar. Sherries generally contain about 8 grs. to the ounce. In Madeira it varies from 6 to 66 grs. per ounce; in port, from 12 to 28 grs. In champagnes the average is about 24 grs., but many of the dry champagnes contain none.

Wine is acid from the presence of free acid and acid salts, such as tartrate of potash. Wines which have been "plastered" or treated with gypsum or plaster of Paris to clear them, as is the case with many sherries, are deteriorated, owing to the loss of their tartrates. The chief acids are tartaric, acetic, malic, tannic, succinic, carbonic, and fatty acids. The usual acidity of wines, in terms of tartaric acid, is about 2 grs. per ounce in sherry, 3 grs. in champagne, 4 grs. in port and the better kinds of claret, and 6 grs. or more in the inferior clarets. The tannic acid is derived mainly from the seeds and skins of the grape; it is largely present in new port, less so in Madeira and the Rhine wines. The amounts of alcohol and degrees of acidity can be determined in wines in the same manner as explained for beer. It is to the mutual reactions of the acids and alcohols in wine that the formation and presence in them of ethers is due, and it is really to these latter that wines owe their special value as stimulants. The colouring matter of wines is derived mainly from the grape skins; by nature it is greenish or blue, but becomes violet or red by the action of the free acids in the wine. As wine ages, changes occur, resulting in a precipitated combination of the organic bodies with tannic acid, whereby the wine becomes pale and less astringent. Occasionally, in the inferior wines, artificial colouring matter is added in the form of the many varieties of aniline dyes, logwood, cochineal, etc. Dupré has suggested the use of cubes of gelatin as a convenient test for distinguishing between the genuine colouring matter of wine and artificial mixtures. When gelatin cubes $\frac{1}{2}$ inch square are immersed in wine for twenty-four hours, if the wine be pure the colour is confined to the margin, while all other colouring matters penetrate deeply into the gelatin; the only exception is rhatany root, the colouring matter of which acts like that of wine. The adulterations of wine are mainly in the direction of added spirit, artificial colouring, and "plastering" to secure clearness and dryness.

The term "dryness" as applied to wines is meant to express a flavour which is not that of sweetness. It has already been explained that the fermentation of grape juice in the formation of wine is the result of a vegetable growth—that of a microscopic fungus which the *must*, or juice of the grape, obtains spontaneously from the atmosphere. Two distinct effects follow the growth of this fungus or process of fermentation: one is, the sugar of the must or grape juice is converted into alcohol; secondly, the greater part of the albuminous or nitrogenous part of the must is consumed as food by the fungus. If left alone, the fermentation goes on until either all the sugar is used up or until the supply of sufficient albuminous matter is exhausted. Now, it will readily

be understood that the relative proportions of these present determine which of the two gets exhausted first; and if the sugar is used up before the albuminous food of the fungus, a dry or not sweet wine is produced, while if the nitrogenous food is exhausted first, the remaining unfermented sugar produces a sweet wine. Since the juice of the ripe grape contains from 10 to 30 per cent. of sugar, there is a very wide range.

A large number of people dislike sweet wines, hence the demand for what is called a dry wine. From what has been stated as to the difference in origin of a naturally sweet wine and a naturally dry wine, it will be apparent that the poorer the grape the drier the wine made from it; but the yield from a poor grape is less than that from a rich one, hence naturally dry wine costs more to produce than naturally sweet wine. It will also be apparent that the conversion of naturally sweet wines into dry ones will not be difficult, and since there is a demand for dry wines the artificial conversion is frequently performed. It is carried out either by making the wine from unripe or poor grapes, in which case the yield of alcohol and flavour are both low; or it is done by adding some nitrogenous material such as gelatin, isinglass, or white of egg to the must, so as to feed the yeast fungus until all, or nearly all, the sugar in the grape has been converted into alcohol. This procedure is sometimes called *fining*, in the wine trade, and is the least objectionable of all methods of artificial drying, being, as it is, almost identical with the natural cause of wine dryness. Unfortunately, there are other methods adopted which are less commendable but more common. These consist often in making an imitation of the natural dryness of wine by adding factitious salts and fortifying with alcohol. The sugar still exists as largely as before, only its taste is disguised.

Perhaps the most general method of increasing the dryness of a given wine is that of adding mineral acids and mineral salts, more particularly gypsum, or Spanish earth. This is technically known as "plastering," because gypsum is plaster of Paris. This being largely sulphate of lime modifies the chemical characters of the wine by decomposing the cream of tartar or potassium tartrate into calcium tartrate, potassium sulphate, and free tartaric acid, at the same time altering the colouring matter and changing the neutral organic compounds which exist in grape juice. The use of gypsum materially clears a wine, making it look brilliant; this is explained by the fact that the resulting sulphate of potash is much more soluble than the antecedent tartrate of potash. To a certain extent, after the addition of gypsum, much of the tartaric acid of wine is replaced by sulphuric acid, a body which renders wine, so altered, distinctly unsuitable for daily use. The sherries

suffer the most from plastering—so much so, that some chemists advise that the plastering of wines should be called adulteration.

The nutritive value of the wines is small, and in the main subsidiary to the stimulating properties of their contained alcohol. The clarets and lighter wines are more or less antiscorbutic, owing to the presence of the organic acids. Port and sherry appear to predispose to gout. The presence of some albuminous principle in wine may give it a slight nourishing value, but in favour of such a view the evidence is small.

Of all the alcoholic beverages, spirits contain the largest amount of alcohol. They are all made by the distillation of alcohol from the fermentation of various saccharine or starchy materials. The more common spirits in this country are brandy, whisky; rum, and gin. The basis of all of them is ethylic alcohol, mixed with water; but they all contain other alcohols, usually classed together under the name of fusel oil, various compound ethers, and fragrant bodies produced during distillation. It is the varying proportions of these latter which give the respective spirits their characteristic taste and aroma. After being kept for some years, spirits become mellowed or softened down; this was formerly supposed to be due to the diminution of the so-called fusel oil, but it is now more generally regarded as due to a lessening both in quantity and quality of the empyreumatic or flavouring substances.

Brandy is made by the distillation of fermented grape juice. When first distilled it is colourless, but gradually darkens with age, though too often artificially coloured by means of burnt sugar. Pure brandy consists of water, alcohol, acetic acid, acetic and œnanthic ethers, a volatile oil, colouring matter, and tannin. It usually contains from 46 to 55 per cent. of alcohol. The best kinds come from France, the more inferior from Spain, Portugal, and Italy. The chief adulterations are water, cayenne pepper, burnt sugar, and acetic ether. Some of the cheaper brandies are not made from grape juice at all, but are mere imitations, made from corn spirit, flavoured and coloured. According to Blyth, a very usual process of making brandy artificially in England is to add to every 100 parts of proof spirit from $\frac{1}{2}$ to 1 lb. of argol, some bruised French plums, and a quart of good Cognac; the mixture is then distilled, and a little acetic ether, tannin, and burnt sugar added afterwards.

Whisky is really one of the corn spirits, being made from malted grain. The more inferior kinds are prepared from oats, barley, or rye, or from potatoes mashed up with malted barley and then roughly distilled and burnt in order to give it the peculiar smoky flavour characteristic of some varieties. Whisky

usually contains from 40 to 50 per cent. of alcohol. Its adulterations are much the same as those of brandy.

Rum is a spirit obtained by distillation from the fermented skimmings of sugar-boilers or the drainings of sugar-barrels (molasses). Like brandy, it is colourless when first distilled, but it is later on artificially coloured with burnt sugar. Rum is chiefly made in Jamaica, and, owing to the habit there of putting a few slices of pine-apple into the best qualities, it is often flavoured with that fruit. The peculiar flavour of rum is due to butyric ether and a volatile oil; the amount of alcohol present in rum is from 50 to 60 per cent. An imitation flavouring identical with that of the Jamaica rum flavoured with pine-apple is made by distilling butter with sulphuric acid and alcohol, and then, by means of the resulting butyric compound, a factitious rum can be made from malt or molasses spirit.

Gin in this country is usually made from a mixture of malt and barley, flavoured not only with juniper berries but with oil of turpentine, orange peel, and several other aromatic substances. In Holland it is made from unmalted rye and barley malt, with juniper berries. In consequence of the juniper and turpentine contained in gin, it is a direct stimulant to the kidneys. It usually contains from 49 to 60 per cent. of alcohol. Its chief adulteration is water, which makes it turbid; to remove this, alum and acetate of lead are employed, followed by the addition of sugar and cayenne pepper to sweeten it and give it pungency. Speaking generally, gin is the spirit of which most is annually consumed by the public, and the spirit which is most often adulterated.

Unless expressly stated to be otherwise, brandy, whisky, and rum are expected by law to be sold of not less alcoholic strength than 25 degrees below proof, while gin should not be less than 35 degrees under proof spirit; of course, in the other direction, or over proof, there is no limit.

CHAPTER IV.

SOILS, SITES, AND BUILDINGS.

THERE is every reason to believe that originally our earth was in a molten state, and that in the course of ages it gradually cooled down, forming a sort of solid crust round a liquid core. After this crust of the earth, as it were, had solidified and become what we call *igneous* rock, or rock produced by the action of fire, it was

subjected through long periods of time to the wearing action of rain, frost, and wind, with the result that much of it was worn down into fine particles, which, collecting together, contributed to the formation of another class, called secondary or *sedimentary* rocks.

Soils.—Now, it is of these two kinds of rocks that the great mass of the earth is composed in the present day, examples of the igneous rocks being granite, basalt, and volcanic lava, while representing the sedimentary rocks are the various sandstones, greensands, limestone, chalk, gravel, and clays. The surface of the ground, or soil, is really only the result of the gradual wearing or breaking up, as it were, through many ages, of these various rocks of which our globe is mainly constituted. It is convenient to divide the soil into two parts—namely, a deeper portion, or *subsoil*, consisting chiefly of inorganic materials, the direct result of the breaking up of the rock under various agencies; and an upper portion, or *surface soil*, which, again, is derived partly from the inorganic subsoil and partly from the products of the decomposition of animal and vegetable (organic) matter.

The nature of the surface soil varies considerably in different places, consisting not only of the decayed upper surface of rocks beneath, mixed with the remains of animal and vegetable matter, but also of much alluvial deposit, or material brought by running water from neighbouring or distant districts. To this action must be added the constant transposition of soil by earthworms, ants, moles, rabbits, and other animals, the general effect of which is to disintegrate the soil, riddle it with holes or burrows, and to admit air into its deeper parts.

Allusion has been made to the presence in the surface soil of the products of the changes which organic substances undergo in it. These changes, which are chiefly in the direction of oxidation, but occasionally in that of reduction, are largely the result of the action of bacteria present in the soil, these micro-organisms being much more numerous in the superficial layers than at a greater depth. The most important property possessed by soil, owing to the presence in it of micro-organisms, is that of nitrification, whereby organic matter is decomposed into its simplest constituents, so as to be readily made use of by vegetation. Plants are unable to obtain their supply of nitrogen direct from complex organic bodies, but, thanks to the action of the bacteria, these are so split up that their nitrogen becomes converted into ammonia, thence into nitrites and nitrates, in which form plants can take up their required nitrogen. Earth which has been rendered free from living bacteria, by heating or other methods of sterilization, appears to be not only incapable of producing nitrification, but also unfit for the growth of plants. Although the greater number

of the bacterial forms present in the upper soil layers are incapable of causing disease in man, still, certain micro-organisms which are capable of producing human disease are occasionally met with in the earth. The chief of these are the bacilli of tetanus or lock-jaw, of anthrax or glanders, of enteric fever, and of a peculiar disease known as malignant œdema. The particular micro-organism associated with malaria is probably also an inhabitant of the soil, while those producing cholera and epidemic diarrhœa are not unlikely also soil residents. That micro-organisms capable of causing disease in man do exist in soil is beyond doubt, but, fortunately, their power for doing harm appears to be extremely small.

In a general sense, as influencing health, soils need to be considered not only as to the nature and number of their contained micro-organisms, but also in regard to the amount of moisture and air in them and their capacity for heat. The moisture in soil is derived from two sources—namely, from the rain, and from the subsoil water beneath. If a hole be dug in any soil, a certain spot will be reached, at a varying depth, at which all the soil interstices are full of water—that is to say, at and below this depth there is a continuous sheet of water known as *ground water*, or subsoil water. The depth at which this will be found, of course, varies in different places, being in some localities within a few inches of the surface of the ground, and in others only some ten to hundreds of feet below. Above the level of the ground water the soil is kept moist by capillary attraction and by evaporation of the water below, by rainfall and by movements of the ground water; on the other hand, the upper soil layers are constantly losing moisture by evaporation from the surface and through vegetation. When the ground water rises, it forces air out of the soil, and at the same time may pollute wells by bringing into them the washings of impure soils. When it falls again it leaves the soil, of course, moist and full of air. The variations in the movements and height of the ground water are conveniently measured by noting the water-level in wells; but, to be reliable, this needs to be done frequently and simultaneously in the wells over a large area, so as to avoid any error due to purely local conditions.

The nature of a soil will largely influence the amount of moisture which it will take up or retain, and practically there are no soils which are not capable of holding some moisture. In regard to water, all soils have two actions, namely, permeability and absorbability. The permeability of a soil to water is practically identical with the speed at which percolation takes place through it. Observations show that water passes most slowly

through clay, and with increasing swiftness through marls, loams, limestones, chalks, coarse gravels, and fine sands. Even through chalk, percolation is by no means rapid. Percolation is most rapid when soil is saturated with moisture. The amount of moisture retained by a soil depends mainly upon its absorbability, and this being largely a result of capillary action, varies with the coarseness or fineness of the pores of the soil, and is greater for soils which consist of fine particles. Thus, granites will absorb from 0·1 to 0·4 per cent. of moisture; slates, 0·2 per cent.; limestones, 2 to 13 per cent.; sandstones, 3 to 8 per cent.; chalks and clays, 17 to 20 per cent.; marls and loams, 30 to 50 per cent. The moisture present in any soil sample is easily estimated by weighing it before and after drying, and then calculating out the difference in weight as a percentage of moisture. From results obtained by many observations, it would appear that the capacity of soils for moisture increases with the amount of organic substances present; decomposition is most active in soils when the moisture is about 4 per cent., but can continue when it is as low as 2 per cent.; any excess over 4 per cent. seems to retard decomposition changes in soil.

Above the level of the ground water, all soils contain air, and this is sometimes called the *ground air*, because it fills all the space not occupied by either water or solid particles. Its amount varies with the degree of looseness of the soil, some sands containing as much as 50 per cent. of air. In its composition, ground air more or less resembles that of the atmosphere above the earth—that is to say, it contains moisture, organic matter, oxygen, nitrogen, carbon dioxide, and occasionally ammonia, marsh gas, sulphuretted hydrogen, and other products of fermentation and decomposition. The oxygen in ground air decreases with the depth, while the carbon dioxide increases with the depth below the surface. If we bear in mind the processes which are constantly going on in the soil, this is just what we might expect, because the oxygen of the air on passing into the soil combines with the carbon derived from the animal and vegetable matter present, producing large quantities of carbon dioxide. The amount of nitrogen in ground air is almost constant, and usually is about the same as present in the atmosphere.

The proportion of carbon dioxide in soil air increases not only with the moisture, but also with the temperature of the soil, the maximum being attained in July, and the minimum in January. The ground air, like the ground water, is constantly moving, the chief influences being wind, the percolation of rain, the rise and fall of ground water, and variations in temperature and barometric pressure. Heavy rains will not only force ground air to a deeper

level, but will also force it out of the ground at places which are dry, as, for instance, the basements of houses. The effect of variations in level of the ground water in producing corresponding movement in the ground air has already been mentioned; while probably of even greater importance are the changes in temperature and barometric pressure. The temperatures of the atmospheric and ground airs are seldom the same, with the result that there is a constant ebbing and flowing of air in and out of the soil. As illustrating these effects of different air temperatures, allusion may be made to the aspirating power which warm houses, unprovided with impermeable basements, have in drawing air up out of the ground. A case is on record in which an escape of gas took place from a pipe 20 feet under the ground; the gas smell was noticeable in houses above, although no gas was laid on to them, the same having passed through foundations, cellars, and floors into the rooms above. In the same way, foul air from defective drains may contaminate houses unless an impermeable layer is placed between the house basement and the ground. Connected with this point is the idea whether the prevalent custom of covering roads and streets in our towns with stones and other impermeable materials does not favour the ground air being drawn in large and dangerous quantities from more or less polluted soils into houses, the basements of which are rarely protected by a concrete layer.

The percentage of air in a soil is best estimated by using two graduated glass burettes connected together at the bottom by a clamped tube. One burette is filled with water and the other with dried and finely powdered soil. By opening the clamp, the water will, of course, pass from one up through the soil in the other, expelling as it rises all the air in the soil. After being allowed to run in until the water just reaches the soil surface, the following calculation will give the percentage of air present in the soil:—

$$\frac{\text{Amount of water used}}{\text{Amount of dry soil used}} \times 100 = \text{percentage of air.}$$

Not only do some soils contain more moisture and air than others, but they are also more easily heated. These variations depend mainly on their looseness and colour. To a certain extent, variations in the heat of soils depend upon that of the atmosphere, the daily variations ceasing to be susceptible below 4 feet from the surface. As a general rule, it may be said that the surface soil is warmer by day and colder by night than the air; and that, owing to the slow heat-conducting power of soils, the changes in the surface temperature are not felt in the subsoil

until long after they have taken place at the surface, so that the subsoil reaches its greatest and lowest temperatures later than the surface soil, and that the subsoil is colder in summer, but warmer in winter than the surface; this in turn again being in cold weather higher than that of the atmosphere, and just the reverse during hot weather. The temperature of any soil depends mainly upon its relative power for absorbing and radiating heat. The absorbing power of soils for heat varies much according to their geological formation and colour, while their radiating powers depend rather upon the kind and thickness of the vegetation growing on them.

Sands not only warm more rapidly than other soils, but also appear to retain their heat better, while clays not only warm more slowly than sands, but lose heat more rapidly. As judged by their relative power for losing heat, soils appear to stand in the following order:—Clays, loams, marls, chalk, and sands. As a rule, dark soils warm more rapidly than the light-coloured ones; and all soils usually cool more quickly than they heat, particularly when vegetation is abundant. Owing to the slowness with which water absorbs heat, all moist soils are slow to warm, and, as such, invariably constitute what are called "cold soils." At first sight, it may not appear that the temperature of the soil has any very important bearing upon health, but apart from its influence upon the various processes of either decay or oxidation going on within the soil itself, the temperature of the ground has a direct influence upon the temperature of the atmosphere and also upon many of the conditions which are implied by the word "climate." In this connection, the relative degrees of warmth or coldness, of dryness or moistness, of purity or impurity of soils, are of the very greatest importance in estimating the value of any particular soil or ground as a site for dwellings or buildings.

Sites.—Although the choice of sites for our houses in towns and villages is usually sacrificed to expediency or necessity, and more often than not fixed upon regardless of the advice of any one, still, some knowledge of the chief considerations which should rule the selection of a building site is none the less necessary, because, if we ever do have a choice in the matter, it is as well that we should know how to choose, or at least understand what to avoid, in making our selection. This question involves the following considerations:—

1. The aspect or exposure to wind, light, and air.
2. The ground or soil on which it is proposed to build.
3. The surroundings of the site.

In considering the aspect of any particular site, it may be said that the brightest and most airy house is usually the healthiest;

but while it is necessary that a house should be so situated that there is a free circulation of air about it, it is advisable to avoid exposure to a prevailing cold wind, and, if possible, shelter from this should be secured by means of a belt of trees or some rising ground. The door or entrance should equally be protected from the prevailing wind either by actual position or by means of some special protection, such as a porch Every house should have, both in front and back of it, an open space at least equal in length to its own height, so as to allow sufficient light and ventilation for the rooms on the lowest floor

In this country the living rooms should, as far as possible, face the south and west, so as to be both bright and cheerful The north is best allotted to working-rooms and the dining room, as twilight lasts longest there, the staircases are also best when arranged upon this side of the house, being always cool For the larder, pantry, or dairy, this aspect is exceptionally good Bedrooms will be found most comfortable when facing the north-east, as they get a pleasant morning sun, and are correspondingly cool at night The east is suitable for the breakfast-room, morning-room, and library, but not for the drawing-room, as it lacks the afternoon sunshine In the south-east may be placed bedrooms, and for rooms used by the sick this aspect cannot be surpassed for fitness The south is unsuited for dining-room windows, unless there be a good verandah, the south west and west are not good aspects for bedrooms or dining rooms, as, under the influence of the afternoon sun, rooms on this side of a house are apt to get unpleasantly hot Where a bedroom is occupied only as a sleeping-room, aspect is of the least importance. By the aid and study of the compass, the principal points with regard to aspect and light will be readily seen.

In towns, those houses are generally the healthiest which are built in wide roads or squares permitting a free circulation of air. Narrow courts, alleys, and back-to-back houses should be avoided. The evils of these latter houses have been repeatedly pointed out, in them, through ventilation is not to be obtained, their sculleries, store rooms, and pantries are nearly always ill-ventilated, dark, and difficult to keep clean, while their closets have to be built in blocks, and are frequently, if not in an actually public position, at an inconvenient distance. The areas or basements of nearly all houses are unhealthy, being usually dark, frequently damp, ill-ventilated, and rarely wholesome. Although it is important that houses should be freely open to both air and light, still the circumstances of towns and cities prevent these conditions being attained so readily as in

the country. To obviate as far as possible light and ventilation being interfered with by houses being too near each other, it is now ordered in London and in the larger towns that all new streets shall be at least as wide as the houses on either side of them are high, and that no new street be less than forty feet wide.

With the same object in view, it is enacted by the Public Health Act of 1875, that no cellar built or rebuilt since 1848 can be occupied or used as a separate dwelling, and even those which existed before 1848 as separate dwellings may not be now occupied unless they comply with the following requirements: (*a*) The height must be in every part at least 7 feet, 3 feet of which must be above the level of the street. (*b*) An open area at least $2\frac{1}{2}$ feet wide in every part, and 6 inches below the floor level, must extend along the whole frontage; this may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation (*e*) There must be a fireplace and chimney. (*f*) There must be a window at least 9 square feet in area capable of opening; the window of a back cellar let or occupied along with a front one need only be 4 square feet in area. Very similar conditions are laid down for underground rooms by the Public Health (London) Act of 1891.

As regards the ground or soil on which it is proposed to build, our aim should be to secure either a naturally dry place, or one at least easily drained, and into which the drainage from other spots does not and is not likely to flow. For this reason, all low-lying swamps and hollows should be avoided. If the district is generally level, every advantage should be taken of any slight elevation in order that the house may be built as high as possible. If, on the other hand, it is a hilly country, the actual slopes or sides of a hill are not usually good situations for houses. No dwelling should be built close in to a hill, as it is sure to be damp, and proportionately unhealthy. It is preferable to build either on the actual top of a hill or on a terrace or spur some little way off the hill itself. For similar reasons, the banks of rivers, unless well raised above the highest level of the water, are to be avoided. Such localities are difficult to drain, usually very damp, and liable to be flooded.

Wherever possible, the soil or ground itself ought to be porous, such as gravel or sand, which allow of water running freely away, and do not cause it to collect about the house. The next best soils on which to build are rocks, such as granites, clay, slates, limestones, sandstones, or chalk; these nearly always have a good slope, and drain easily. The loams and stiff clays are not

as a rule good soils for building purposes, as, unless well drained, they are apt to hold water; if, however, adequately drained, these are not necessarily unhealthy. Land drainage is effected either by means of deep drains, or by unglazed, porous earthenware pipes, placed at varying depths of from 1 to 3 feet below the soil surface, and about 6 feet apart. Pure chalk forms a healthy site, being permeable; if the chalk be mixed with clay (marl), or be underlaid by clay, it becomes impermeable and damp. If of any thickness, gravel beds make good building sites. The worst soils are the shallow beds of gravel or sand lying on clay; these are frequently waterlogged and proportionately bad; the same remark applies to reclaimed lands near the mouths of rivers, and the so-called alluvial lands, which consist of soils that are really the deposit or sludge from rivers. Alluvial tracts are almost invariably unhealthy, owing not only to their dampness, but also to the large quantity of organic matter which they contain. These soils and sites are peculiarly liable to produce rheumatism, ague, and various forms of malarial fever, as well as catarrhs and neuralgia.

In towns and modern cities, care should be taken that no artificial site be chosen—that is, one placed upon a so-called "made soil," which is really a soil made up of rubbish. The usual method for preparing such a made soil is to select a plot of ground, remove and sell the surface turf, and then dispose of the surface soil for gardens. After this, the subsoil is dug out and sold as either sand, gravel, or clay. The site is now a large pit in which rubbish of all kinds is tipped until its level is raised to a sufficient height to be regarded as a building site. Very often no preliminary excavation is made, but rubbish invited to be thrown into some natural hollow or low-lying piece of ground until completely filled up. The rubbish usually composing such soils is peculiarly rich in decomposing organic matter liable to give rise to particularly injurious products. It is certainly unsafe to build upon any such made soil until the rubbish of which it is so largely composed has been exposed to the sun and air for quite three years, and even then the dwelling built upon it should have an air-proof basement of concrete, or some impermeable material.

This concrete should be from 4 to 6 inches thick, and may, in some cases, be made to serve as a floor itself, particularly in passages, washhouses, sculleries, and pantries. If the expense of this be objected to, a layer of well-puddled clay is probably the next best thing, or, if neither of these arrangements be adopted, and a boarded-floor basement is used, a space of at least 9 inches has to be left between the under side of the floor and the ground

surface, not only for ventilation and as a preservative against dry rot, but also as a means of disconnection between the soil air and the air of the house. In some places it is necessary to raise the building on arches to keep it sufficiently clear of the ground; but, in any case, there ought to be some distance between the foundations and the floor of the lowest rooms, while the space so left should be ventilated. As a rule, cellars under houses add to their healthiness, especially if properly built with an impervious flooring, and adequately ventilated.

In all sites, it is important to notice the distance of the ground water from the surface. As already explained, if this water be too near the ground-level, the spot will be damp; it ought never to be nearer the surface than 10 feet, and, if possible, should be at least 15 or 20 feet below the ground-line. There is good reason to believe that frequent, sudden, and extensive changes of water-level are specially unhealthy; therefore a place where the level of water in a well is apt to rise and fall a good deal is not a good site. These remarks apply as much to towns as to country, for often one part of a town may be less healthy than another on account of its situation being lower, and the level of the ground-water higher. Statistics for many years go to show that where the ground-water level has been lowered, and the soil made drier by means of drainage, there the public health has improved. This improvement in health has been chiefly in the lessening of such diseases as consumption, bronchitis, catarrhs, sore throats, rheumatism, and ague.

In judging of the influence of surroundings upon the wholesomeness of a given site, it is necessary to assure one's self that the soil or subsoil is not being fouled by the drainage of any neighbouring building. Thus, when one house lies at a lower level than another near it, it is likely to suffer from the effects of the drainage from the one above. In cases where houses stand alone, as in rural districts, special care needs to be taken that no heaps of farm refuse or manure, cesspits, middens, or other collections of decaying matter are allowed to remain near the house. The immediate neighbourhood of sewage-farms are undesirable, as, too, are the vicinities of factories, chemical works, graveyards, and marshes, the air of which districts are apt to be impure from either refuse or generated gases. The irrigation of adjoining land, as a rule, makes a site less healthy than it ought to be, especially if the irrigation be carelessly carried out, as this raises the level of the ground-water.

Summing up the facts in regard to a choice of site for building purposes, the most essential points to be sought for are as follows :—

1. A moderately elevated spot, with the ground falling away from it on all sides, sheltered from the north and east, but not so shut in as to impede the free circulation of air round and over it.

2. The site should, if possible, be upon a porous soil, such as gravel or sand, care being taken, however, to see that the subsoil is sufficiently permeable to secure thorough drainage, either naturally or artificially.

3. The ground-water should not be nearer the surface than 10 feet, and not subject to either great or sudden fluctuations.

4. The surface soil and subsoil, no matter what their nature, should be clean, and not fouled by either sewage or refuse.

Having then secured a suitable site, the next thing is to see that the building proposed to be erected upon it is so built that it may be regarded as healthy. To that end, it must be so constructed as to be able to be kept free from damp, to be proof against weather, and to maintain the air within it pure and wholesome. These indispensable conditions, applicable equally to the private dwelling-house or to public institutions, involve attention being directed to the way in which the foundations and brickwork are arranged, to the material and state of the outer walls and roof, to those of the inside walls, ceilings, and floors, as well as to the general arrangements of the building, and the means for removing excreta and refuse.

Dwelling-houses.—The foundations ought to be sufficiently solid, and deep enough in the ground to give firmness to the building. When the ground is soft, or a solid foundation cannot be reached, the walls should be built upon a solid platform of concrete or stone, which should be at least four times as broad as the walls. The bases of the walls themselves should be expanded into what are called *footings*, the lowest course of which should be at least twice the breadth of the wall. The height of the footings ought to be not less than two-thirds of the wall thickness.

The situation and nature of the soil may need measures to be taken to prevent damp rising in the walls by capillary attraction, and in order to do this it is necessary to lay a *damp-proof course* along the full thickness of the wall above the highest point at which the wall is in contact with the earth, and below the lowest timbers or floor supports. This course is either made of glazed tile, slate, or sheet lead, asphalte or other impervious material. The walls of no room or cellar should be in direct contact with the soil. This can usually be secured by digging away the earth on the outside to below the level of the floor, so as to form a "dry area." As an alternative plan to this, a device recommended by the Local Government Board in their Model Bye-laws

may be employed; this consists in making the wall hollow up to a point above the ground level, and then inserting two damp-proof courses, one at the bottom of the hollow and below the floor-level, the other at the top of the hollow, and therefore above the outside ground-level. By this means the inner wall is quite shut off from the soil. Both these arrangements are shown in the diagram (Fig. 34).

The materials ordinarily used for the construction of the walls of dwelling-houses are bricks, stones, and wood. In many tropical countries crude or sun-dried bricks are employed, but these are unsuited for this climate, and we have therefore to do with baked

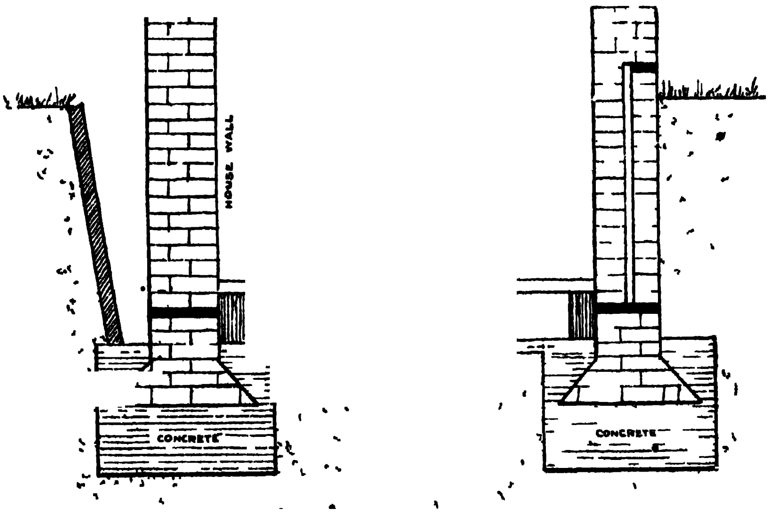


FIG. 34. Diagram showing placing of damp-proof courses.

or kiln-dried bricks. Bricks are made from three kinds of earth, namely, pure clays, marls, and loams. Pure clay consists chiefly of alumina and silica; marls are clays having in addition a considerable amount of lime in them; while the loams are light or sandy clays. Few bricks are made solely from any one of these earths, but rather from an admixture of all three. A good brick should be regular in shape, of a uniform colour, well-burnt, and, when struck, give a clear, metallic ring. Ordinary bricks weigh about 7 lbs., and are $8\frac{3}{4}$ inches long, $4\frac{1}{4}$ inches broad, and $2\frac{3}{4}$ inches thick, giving a total bulk of about 102 cubic inches. They are porous, and readily absorb water, usually from $\frac{1}{6}$ to $\frac{1}{7}$ of their bulk, or say a pint of water. So porous are bricks that both rain

and air can be easily driven through them; in fact, so much is this the case that it is desirable in all dwellings that the outer walls should, if of brickwork, be at least a brick and a half thick (14 inches), so that in addition to the bricks, there may be in the structure of the wall itself a vertical layer of mortar. Mortar is a compound of 1 part of lime with 3 parts of fine clean sand, made up with fresh water; if salt water be used, the mortar dries badly. Owing to bricks having already, during manufacture, been burnt, they stand fire better than anything else, and on this account are superior to any other material for house walls.

Two classes of stone are ordinarily employed for house building: they are sandstone and limestone. Sandstone has been described as sand made into a cake with clay, lime, and oxide of iron. It is the varying amount of this latter which gives the various colours to it, such as red, yellow, and grey sandstone. Limestone is a rock composed mainly of carbonate of lime. Like bricks, stone is both porous and absorbent of water, but in a less degree.

Wood is only occasionally used in the external walls of houses in this country, but enters largely into the construction of the inner fittings of all dwellings. In its natural state it is extremely absorbent, and the unavoidable cracks and crevices admit both air and water. The chief kinds used are ash, beech, oak, elm, pine, and larch. The first four differ from the latter two in being free from turpentine. Good timber should be close and straight grained, free from cracks and dead knots, and well seasoned.

The *walls* of all dwelling-houses should be most carefully built from the foundations upwards, whether of brick or stone, with a layer of mortar not only between each course, but under the first course, and, too, well fitted into the vertical joints. Bricks are laid in beds or courses, and are usually spoken of as being bonded together. There are two ways of laying bricks, called respectively English and Flemish bond. The English bond is a course of bricks each showing one side alternating with a course in which each shows an end (Fig. 35). Flemish bond is a single course of bricks in which they alternately show a side and an end (Fig. 36). The former method is considered to be the stronger. The thickness of the outer walls of dwelling-houses is determined by the size of the building, more particularly by its height. According to the Model Bye-laws of the Local Government Board, the minimum thickness should be as follows:—Where a wall is not over 25 feet in height, if it does not exceed 35 feet in length, and does not comprise more than two storeys, it shall be 9 inches for its whole height, but if it does comprise more than two storeys, or exceed 35 feet in length, it shall be 13½ inches below the topmost

storey, and 9 inches for the rest. Where walls are over 25 feet high, and not exceeding 35 feet in length, they should be 13½ inches thick below the topmost storey, and 9 inches for the rest; but if they be longer than 35 feet, then they must be 18 inches thick for the height of one storey, then 13½ inches thick for the rest of the height below the topmost storey, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two storeys, and 13½ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one storey, then 18 inches for the next two storeys, and finally 13½ for the rest of the height.

Walls built of cut stone need to be no thicker than those of brick, but if of rough stone or flint and boulders, they should be at

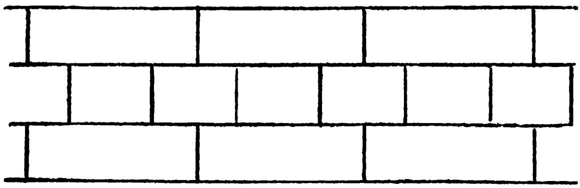


FIG. 35.—English bond.

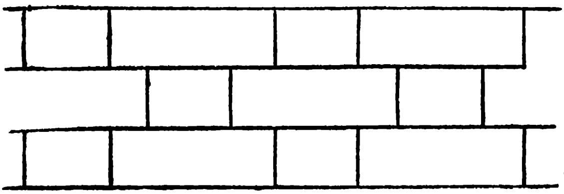


FIG. 36.—Flemish bond.

least one-third thicker. Combination walls made of both brick and stone are not uncommon; the chief point about them is the need of careful bonding together of the two elements. Occasionally walls are made of concrete either rammed down in layers or else built of concrete blocks well cemented together. Wood is at times used in making the upper part of the outer walls of houses; when so employed, it needs to be backed with at least 4½ inches of brickwork, and well bonded together.

Owing to the absorbent and porous nature of all these materials, special care needs to be taken that outer walls constructed of them do not admit damp sideways, especially when in positions much exposed to driven rain and wind. To prevent this, they may be hung over with slate on the outer side, covered with glazed tiles, painted planks, plastered, or cemented. A surface

of mortar sprinkled with small stones is occasionally employed. All these are good plans, provided they are done when the bricks are dry, as otherwise the moisture is kept in the bricks. Painting the outside of a wall with silicate, or some indestructible paint, affords a similar protection, but, like the others, interferes with the insensible ventilation or diffusion of air which so constantly goes on through the walls of most inhabited buildings. Probably the best plan to keep damp from coming through outer walls, is to build them double, with a cavity or space two or three inches wide between the inner and outer walls, and to join the two portions of such a wall together by means of *bonding-ties* of some non-absorbent material, such as iron or glazed tiles. The bonding-plates between the two walls should slope downwards and outwards, otherwise the wet will pass across them to the inner side. In very exposed positions, it may be necessary to place within the wall a vertical damp-proof course of iron or slate. A damp-proof course is needed at the top of exposed walls, such as parapets and chimneys; this is usually provided by finishing the top of the wall either with a stone and letting it project an inch or two over the side, or by having an impervious damp-course laid in the wall or chimney at its junction with the roof. During the building of house walls, care should be taken that chimney flues are properly constructed. They should all be made as straight as possible, and separate one from another. They should contain no woodwork, and if possible be lined with pipes, an arrangement which not only disconnects the flue from the house structure, but favours cleansing and the maintenance of an up-draught. All chimneys should be higher than surrounding buildings, so that they may be in no way sheltered when the wind is in a certain direction, nor a down-draught set up.

Roofs themselves need to be closely considered, as defects in them are a frequent source of dampness. The more common materials used in making roofs are slates and tiles, or less often thatch, wood, zinc, and corrugated iron. Slates, when good, should be hard, free from streaks or flaws, and give a metallic ring when struck; if of poor quality, they are apt to scale and readily break away. Tiles, like bricks, are made from clay, but need more careful drying and burning. Thatch forms a good roof, being both warm and dry, but is apt to catch on fire, and, unless well looked after, is rapidly infested and destroyed by birds and vermin. Wood, covered with tarred felt or canvas, makes an excellent roofing; but, like zinc and corrugated iron, is practically only suited for temporary buildings, and is not adapted for dwelling-houses. Lead is too costly to be used, other than for special parts of the roof. In all roofings, it is

important to see that there is a framework, sufficiently strong to bear the weight of the material, *plus* a certain amount of snow. The framework is usually made of wood. If the covering is to be of slates, the slope of the roof should be 25°; if of tiles, at least 30°; metal roofs may be made flatter. House roofs should always be covered with boarding laid at right angles to the rafters of the framework, and, if possible, with a layer of some good non-conducting material such as felt, which not only makes the house cooler in summer, but warmer in winter. Laths are occasionally substituted for boards in roofs; this should not be, as they are much less satisfactory. When slates are used, they should be fastened to the boards with copper or zinc nails (not iron), and made to overlap the row below them by quite 2 inches. Tiles are often fastened with wooden pegs, or hung on by two special projections. Lead, zinc, and iron roofs are laid nearly flat in widths, with their edges overlapping, to allow for expansion and contraction. In some parts of the country, flat stones are used for roofing, as in the sandstone districts. These roofs are very heavy, and extremely difficult to make water-tight. The gutters round chimneys or party walls, where they join the roof, are frequent places for leaks; they all should be made of lead, the edges of which should be well fixed into the brickwork; cement should never be employed for this purpose, as it readily cracks. In all cases, the eaves of a roof ought to come out some distance beyond the walls, and be provided with a good gutter, so as to throw off the rain well away from the house. These gutters should be of iron, and at least 2 inches from the wall, discharging into rain pipes, which should also be of iron, and placed well outside, and away from the house wall. These rain-water pipes should either discharge into properly ventilated rain-water tanks, or over a drain covered by a grating. They should never be directly connected with drains or sewers, neither should they be placed with their heads just below bedroom windows, more particularly when they empty into a tank.

So far we have considered how to keep the outside walls of the house dry, or at least how to prevent the damp reaching the inside. It is now necessary to consider the inside walls, ceilings, and floors. The inner walls of a house need to be protected and covered in some way, though some people object to it on the ground that it interferes with the porosity of the walls, and so impedes ventilation. In this climate, however, some wall covering is more or less of a necessity. The simplest is white-washing. This plan, however, is not good, as it does not do away with the porosity of the brick, and, moreover, leaves a comparatively rough surface for dirt to lodge and collect. If

walls are white-washed, the wash must be frequently renewed. The best plan is to aim at securing, not only an impervious material, but one which has a smooth surface and can be readily cleaned. For this purpose, two plans can be employed; either cover the walls with glazed tiles, or plaster them, and then paint with some form of indestructible paint. Papering walls is very common, but it has the disadvantage that, unless varnished, it cannot be washed, and much dirt sticks. The flock papers and their cheap imitations are particular offenders in these respects. Lime-washing is preferable to common unglazed or flock papers; but it must be borne in mind that the mere putting on of a fresh coat of lime-wash over an old and dirty one is not cleanliness; the wall should be first scraped, and the old coat thoroughly removed. Similar objections exist to the too frequent habit of pasting new wall-papers over old. This often goes on for times together, until half a dozen or more papers are found one under the other. Each of these will have taken up its share of dirt, and each will have been laid on with a fresh supply of paste, so that, on the slightest dampness, the whole has every facility for rotting and fermenting. In all cases, the old paper should be scraped off before the new one is put on.

Ceilings are mostly made of plaster worked on to laths, fixed beneath the floor of a room above, and then either painted, distempered with colour wash, white-washed, or else covered with paper. The only advantage of the lath-and-plaster ceiling appears to be its power of deadening sound. It is probable that for health reasons it would be much better if ceilings were made wholly of wood, but in that case, to deaden sound, they might advantageously be backed by either silicated felt, or silicated cotton, and to avoid dust coming through from floors above, have the wood panelled, and all joints accurately tongued and grooved.

Like wall coverings, *Floors* are best made of impervious materials, which can be washed. Wood, stone, or tile constitute the chief. Stones or tiles are very good for sculleries and passages, but are apt to be cold for kitchens and living-rooms. Wood makes the best flooring, particularly hard wood, such as oak or teak, laid as parquet flooring. These, however, are very expensive; and the ordinary wood floor is usually made of deal. In the majority of cases, floors are badly constructed, ill-seasoned wood being used, which soon shrinks and gapes. Even if made of deal, a floor can be well laid down, if care be taken to tongue and groove the planks which constitute it, or if this be not done, to caulk the seams with tow, and then varnish the whole over. This will permit of its being cleaned by dry

scrubbing or sweeping, and, even if washed, of being quickly dried. Too often, owing to the cracks and crevices in floors, the enclosed space below, between it and the ceiling of the next room, becomes a huge receptacle for dirt of all kinds. As already explained, if the floor be a basement one, and unprotected by concrete or other impermeable layer, or be over an unventilated cellar, foul gases and air find a ready entrance into the room. The necessity for the free ventilation of all closed spaces has been explained, and nowhere is it more needed than in those below basement floors. If the ventilation is insufficient, the air becomes damp, and a fungus growth called dry rot is liable to set in and destroy the flooring. In the upper storeys, however, the ventilation through the boards and ceiling is usually sufficient, unless constantly covered with oil-cloth or some other air-tight material. The skirtings round rooms or floors should, when possible, be of tiles or cement, but if of wood, they ought to be let into a groove in the floor, a device which will serve to prevent draughts coming through, and the accumulation of dust in the holes or cracks, which are invariably formed by the shrinking of the joints and skirtings. If floors were made better, so as to ensure a more or less uniform and impervious surface without cracks, or badly made joints, through which draughts can enter and dust collect, there would be less inducement to cover the whole floor area with a carpet or drugget as is so commonly done. If carpets are used, they should be sufficiently limited in size as to leave a border of bare flooring round the room. This arrangement does not allow dust to accumulate readily in corners, and at the same time simplifies the taking up and beating of the carpet.

Having chosen a site, and entered into some detail as to the building and construction of the dwelling-house, it remains to consider the chief points as to its design and arrangement. In all efforts to plan a house, the great object is to make every use of the whole space, in order to get as much accommodation and comfort as possible. When we have to consider small cottages there is seldom much choice in the matter. In no case, however, should privies, middens, or pigstyes, etc., abut upon or form part of a dwelling-house; neither ought houses to be built back to back. If possible, rows of houses should run north and south, and all square buildings should have angles in those directions, so as to get some sunlight in every room. In dealing with houses of a better class, there are several points which call for notice. One of the most frequent errors is the cramped space allowed for halls and staircase. Plenty of space should be given for them, as with ventilating windows at the top they constitute the central ventilation of the house. All the rooms ought to be so placed as

to get light and air directly from the outside; and if there be any passages or lobbies they should be similarly lighted and aired. No room or closet which has, so to speak, a borrowed light, and is not in direct communication with the outer air, ought to be used as a sleeping-room. Equally it is undesirable to use a kitchen or room in which food is prepared or kept as a sleeping-room. The size and allotment of rooms will of course depend upon questions of cost, convenience, and the purpose for which they are intended. The kitchens and larder ought to be on the cool side of the house, which we have already explained is in this country the north side. It has been suggested that the kitchen should be put at the top of the house, so as to allow smells and vapours of cooking to rise into the air instead of into the house, as when the kitchen is in the basement. Theoretically, this is a very good plan, but practically only possible in a very limited number of houses. Its general adoption, particularly in small houses, would be impossible.

The height of rooms should not be less than 9 feet, and rarely need exceed 12 feet. Every room should have at least one window in it which opens to the outer air direct; if possible it should open half its size, extending nearly to the top of the room and equal in area to at least one-tenth of the floor space. Among other requirements in a good window it should be so made as to permit of being cleaned by a person standing inside the room, whereby the risk and expense of cleaning from without are avoided. This involves the abandonment of the sash window and the adoption of one so divided that one-half vertically, or in large windows one-third, may open inwards on hinges, the other half or two-thirds being fixed and wind-tight, the breadth of each division to be such that a servant's arm can reach out and clean the outer side of the fixed window when standing inside the room. The use of skylights in the place of proper windows is not permissible. In addition, every habitable room must have either a fireplace or some special ventilating aperture or air-shaft, the sectional area of which should be not less than 100 square inches.

In the chapter on "Ventilation" allusion has been made to the various and best means of warming the dwelling. A few remarks here may not be inappropriate, relating to gas-pipes, water-service pipes, and hot-water supply arrangements. Very few houses now are without a gas supply, simply because it is relatively both cheaper and more convenient than lighting by candles or oil lamps. Few people have a choice as to the source of their gas supply. In general terms, it may be described as a mixture of carburetted hydrogen with various other hydrocarbons distilled

from coal in retorts, and, after purification, delivered by public companies to individual tenements. Every house supplied with gas has a meter, or arrangement for measuring the amount supplied. This meter should always be a dry one, as what are called wet meters contain water, and this being liable to freeze in cold weather, may cut the supply of gas off altogether. Owing to gas being always stored in the gasometers over water, it readily absorbs it, and rapidly deposits it again when reduced in temperature. The result of this is, all gas tends to deposit moisture in the pipes which deliver it. This naturally collects in the lowest sections, and the gas can only get through it in bubbles, causing the well-known flickering of the flame. During frost, this may form a solid and impermeable obstruction. To obviate this, and prevent water lodging, a small pipe should be connected with the lowest part of the domestic service and fitted with a tap to draw off any collection of water. Supervision is needed to see that gas-pipes are not hidden in walls or behind woodwork, where nails are liable to be driven in and puncture them. Care needs to be taken to see that all joints and fittings do not leak, as any such defects are a fruitful source of gas explosions, besides which there is reason to believe that the escape of minute quantities of gas from defective fittings, especially in bedrooms, often causes headache, sore throat, and other conditions of ill-health. The sliding gasaliers and pendants are all sealed with water-traps; these require to be systematically refilled to prevent their running dry, and so allowing gas to escape. The placing of a little oil on the top of the water after having filled the tube will commonly prevent loss of water by evaporation. Too much care cannot be given to the choice of a good burner; the relative value and effect of some of them has already been referred to. The regulation of gas pressure may be arranged by a governor to each burner; but, as a rule, this is unnecessary, as one governor or simple contrivance for regulating the gas pressure is commonly attached to the main pipe after passing through the meter, and quite suffices to secure a steady flame with no waste. An excellent example of these governors is Stott's gas-valve, which, from its compactness, steadiness, and sensitiveness to pressure changes, affords the individual consumer full control over his gas supply.

In the chapter dealing with "Water and Water Supply," reference has been made to the materials of which pipes are made. Dealing as this chapter does with the construction of the house itself, it is important to remember that, in planning or building a house, the greatest care should be taken to see that water-supply pipes are not so placed as to be readily affected by frost. All outside

walls should be avoided if possible; if necessity compels pipes to be exposed, they should be surrounded with casings of sawdust or wrapped up in felt. Branch pipes should be as few and short as possible, and made to go off at an acute angle in the direction of the flow. Cold water should be available, and laid on to sinks in

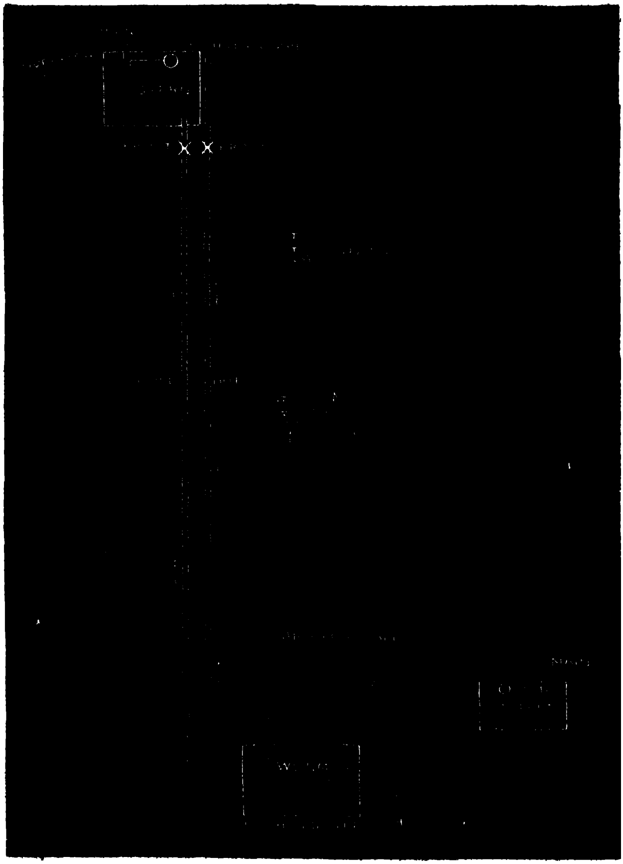


FIG 37 —The worm boiler hot-water apparatus.

the kitchen and scullery, to the bath-room—if such exist—also to the cistern for flushing closets, and in cases where no constant supply is laid on, to a separate storage cistern. It is usually convenient when a house is in connection with a public supply to have the water delivered in the kitchen and scullery direct from the main; a similar supply from the main should, if possible,

be delivered to the upper floors. In the best houses now, all taps which deliver water from the mains are marked "main," while those which yield water from cisterns are marked "cistern." This detail ensures greater care in the placing of fresh water in bedroom bottles, and avoids the issuing indiscriminately of stored water, it may be rain water, from cisterns for both washing and drinking purposes. Whenever possible the use of storage cisterns for water should be avoided. Most water companies take care to lay their supply pipes deep enough in the soil (2 feet) to protect them from freezing; such pipes should be fitted with a stopcock or valve for cutting off the water during emergencies, such as leaks or frosts. Where pipes run horizontally, care should be taken to see that they are laid on continuous supports, and at a slope sufficient to run off their contained water when it is required to empty them. When pipes run vertically they are best fastened to wood rather than to masonry.

Hot-water Supplies.—Most modern houses, excepting the smallest, are fitted with a hot-water supply, and this, unless skilfully devised and efficiently constructed, is likely to have unexpected consequences of a serious nature under any unusual stress, such as may be brought about by a frost of exceptional severity. The earliest form of hot-water supply was that known as the worm-boiler system. This is still occasionally met with, is safe provided the supply of water in the boiler is attended to, but not very satisfactory for getting hot water, as the hot supply for the kitchen being drawn from the boiler itself and not from the worm system, if much hot water be taken from the boiler in the kitchen, the hot supply to the rest of the house is cooled down (Fig. 37). On the other hand, it is safe, as the little feed cistern for the boiler is too near the kitchen to freeze, and so long as there is water in that so will there be water in the boiler. Even if the pipes of the worm system freeze, no explosion will follow, as the heat, being derived from water, is never sufficient.

Of more modern methods there are two, namely, one with a reservoir and one without. The so-called reservoir hot-water service is shown in Fig. 38, and is a very effective arrangement. Its essential feature is the introduction of a metallic reservoir, usually of copper or galvanized iron, capable of bearing a pressure of 20 lbs. to the square inch, and placed between the cold and hot supply so that its contained water is heated by circulation from the boiler. This circulation of water through the system is maintained by the fact that hot water being lighter than cold escapes or ascends through the pipes in the top, and having given up some of its heat above, returns cooled by the lower pipe. The danger during frost for this apparatus exists in the possibility

of both the supply and escape pipes getting frozen, in which case the water in the reservoir might get to a rapid boil without the plug of ice in the hot escape being thawed. This is largely theoretical, and rarely likely to happen with hot circulating water so near. A greater danger exists if the supply pipe gets frozen and be undetected, in which case the boiler and reservoir after some length of time might boil dry, but before this could occur there would certainly be signs of unusually vigorous boiling going on in the reservoir to suggest that something was wrong.

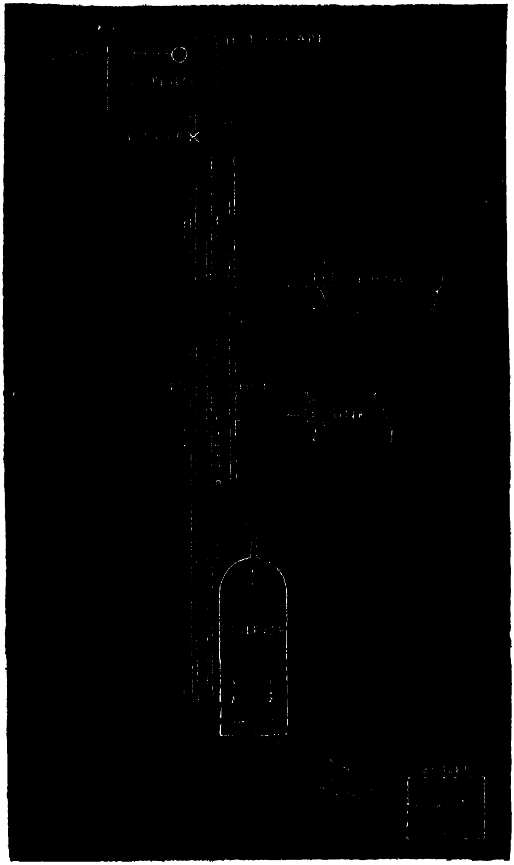


FIG. 38.—The reservoir hot-water apparatus.

An inferior and dangerous hot-water apparatus is shown in Fig. 39. It consists of a plain boiler at the back of the kitchen fire, having a cold feed-pipe entering its bottom from a supply cistern placed at the top of the house. From the top of the boiler runs a hot supply pipe which goes to various parts of the house, and ends as an open escape pipe over the top of the cistern. So long as it is in good working order this arrangement is efficient, but during frost both pipes are apt to get frozen and blocked at X X, simply because they are usually near the roof and exposed to cold. If the fire be lit and the water boil, no steam can escape by either pipe, the result being an explosion. Sometimes instead of both pipes getting frozen only

the cold feed to or from the cistern is blocked. In a while the water that was previously in the boiler boils away, the boiler itself gets red hot, and if suddenly the cold supply be renewed or let in, the cold water rushing into a red-hot boiler gets so rapidly converted into steam that a violent explosion follows.

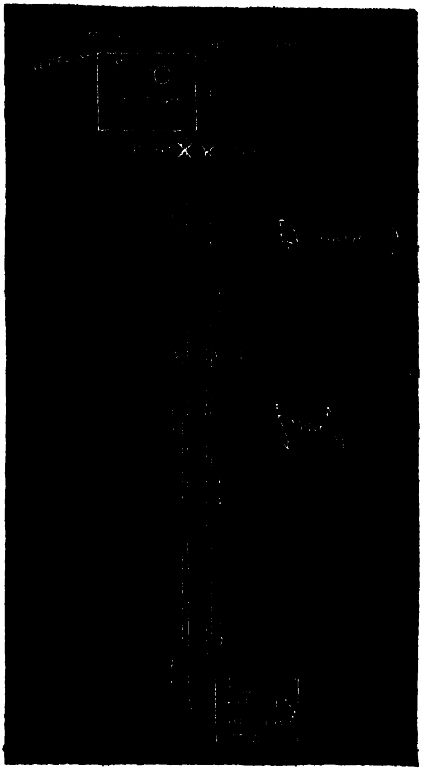


FIG. 39.—A dangerous hot-water apparatus.

To meet dangers and difficulties of this kind in connection with frosts several proposals have been suggested. The best and most effective measure to adopt when a frost is anticipated, is undoubtedly to run off all water out of the system and shut off the supply from the main over night, taking care of course to see that the supply is renewed before the fires are lighted again in the morning. Unfortunately, this is difficult to always put into practice. Others have suggested that taps should be left running in order to prevent the freezing of the water in the pipes. This practice is illegal, inasmuch as it causes a waste of water and renders the householder liable to penalties; moreover, if extensively practised in low-lying districts, would automatically cut off the supply to higher districts. Probably next to emptying the pipes completely and disconnecting them from the main during the night time, the better plan in all cases, where kitchen boilers are used for furnishing hot water on a high-pressure system, is to arrange a storage cistern, sufficient to contain forty-eight hours' consumption in a protected position above the highest draw-off tap; while all pipes supplying the boiler ought to be so protected as to absolutely prevent freezing in the most severe weather. For absolute security, it is recommended that a safety-valve should be fitted

to every kitchen boiler; of these, none are so simple or reliable as those of dead-weight construction without either guide, spindle, or wing, so that there is no fear of their sticking fast. The safety-valve should be fixed as near the boiler as possible, the connecting pipe not being more than 6 inches in length. It should be enclosed in a small cast-iron box with a hinged door so as to be protected from injury, and at the same time admit of being examined whenever necessary. To see that the pipe connecting the boiler with the valve is open, the valve should be occasionally lifted, and if the water squirts out it will show that this is so. Such valves can be fitted at trifling cost, will wear for years, and at the same time afford full and reasonable security against the undue accumulation of steam pressure within the boiler.

Any noise occurring in connection with a hot-water service is usually due to air in the pipes, or deposit choking some pipe. It may be a warning of danger, and should invariably be inquired into. Owing to their fouling or furring inside from hard waters, boilers need to be cleaned out periodically. These internal incrustations may be a cause of a boiler not heating readily, but more often this defect is due to foul flues, the result of neglect on the part of servants. If the flues be foul, naturally the up-draught is lessened in them. All hot-water pipes should be allowed plenty of room for expansion and contraction.

Artisan Dwellings.—The agricultural labourer's cottage should at least comprise a living-room with small scullery attached and sufficient bedroom accommodation, say one room for the parents and two for the children. The most economical arrangement for this amount of accommodation is in a two-storeyed building, the height of the lower storey of which should be 9 feet and that of the upper not less than 8 feet. The living-room ought to have a minimum floor area of 150 square feet, and be fitted with a cupboard for storing food, lighted and ventilated by a separate window. The scullery adjoining the living-room should be 10 feet by $7\frac{1}{2}$ feet, and if possible, a pantry entered through the scullery, light, cool, airy, and, above all things, dry. The parents' bedroom ought to have about 80 feet of floor area, and those for the children 50 feet; all the rooms should have fireplaces in them. The privy accommodation and places for deposit of refuse are in these houses best placed in a shed out-of-doors. The distance at which this is placed should not be excessive, neither should groups of closets common to two or more houses be placed in yards in which children play, women hang out their washing, or men and boys loiter. Such arrangements are objectionable, not only on account of decency and morals, but also as tending to deter

inhabitants from using the closet as freely as might be desired; as well as offering unnecessary facilities for the spread of infectious disease present in any one dwelling to the inhabitants of the others, through the medium of these privies and ashpits.

The dwelling of the town-living artisan offers greater difficulties in arrangement, because it is usually necessary to place it upon sites where land is expensive and limited in extent. The separate houses as usually built in rows should differ little from the standard just given for the country labourer with a family; but the modern blocks of artisan dwellings occasionally present unnecessarily objectionable features. Some of the earlier built dwellings of this class were arranged on both sides of a main corridor 8 feet wide in each storey. This corridor arrangement besides conducing to want of privacy and independence, involved much difficulty in regard to both light and ventilation. A further defect in some of these blocks is the provision of a water-closet as an integral part of each dwelling, and too often so placed as to be a source of danger to health. The corridors should be dispensed with, and each dwelling be made independent of its neighbour for air by having vertical series of dwellings only on each side of one or more staircases, the other side of the dwellings being open to the outer air. The water-closet accommodation should be improved by rendering it accessible from each dwelling from the external air by means of some sort of covered way or balcony; while, by wholly detaching the blocks of buildings, confined angles and stagnant corners will be obviated.

In the better class of house, one of the most frequent errors is the position of the water-closet, which is often close to the bedrooms or even kitchens, and not in the least disassociated from them. Sometimes the water-closet opens out of a bedroom, often with no communication with the outer air, or at most, ventilated into a passage or hall. The proper situation for a water-closet is a separate or outstanding part of the house, and where there are several water-closets these ought to be built one over the other, and quite confined to one part of the building. Some authorities go so far as to suggest that every closet should be cut off from the rest of the house by close-fitting doors and a well-ventilated lobby. These arrangements, however, for the separation and isolation of closets would be and probably are unnecessary, if the closets themselves are of the best construction and efficiently disconnected from the drains. Unfortunately, this condition is not always the case, hence the need of some general arrangement as explained above.

Each closet ought to have at least one window of a minimum superficial area of two square feet opening direct into the outer

air, also have a second opening, such as either a Tobin tube or a ventilating brick, so as to secure a circulation of the air independently of the house. The closet walls ought to be covered with glazed tiles, painted plaster, or varnished paper, the ceiling, too, ought to be varnished or painted. The floor may be of tile or cement, or if of wood, well caulked and varnished.

The details relating to the removal of both liquid and solid refuse and excreta from houses are discussed in the next chapter; but, dealing as this chapter does with the habitation itself, it is here necessary to consider what arrangements are needed to receive the excreta and refuse before they pass into the proper channels of removal. These arrangements usually comprise the ordinary water-closets, sinks and baths, slop-closets, trough-closets, privies of various kinds, dry-earth closets, ashpits, and dustbins. The closet apparatus itself ought to be the simplest that can be obtained consistent with efficiency, and as a rule it may be stated that the more complicated the arrangement, the less likely is it to be either efficient or perfect. The question of the precise kind of closet to be adopted, whether on the water principle or on some dry principle, is dependent mainly upon the special circumstances of the place.

Closets based upon a water system for the carrying away of excrement are practically of three kinds, namely, (*a*) the ordinary indoor water-closet as found in the majority of the better class houses; (*b*) slop closets, or those in which the excrement is washed away down the drain by the waste liquids of the household instead of by clean water supplied for that purpose; (*c*) trough-closets, or those connected with a trough containing water, and common to two or more seats, such as are met with in schools, factories, and other places of common resort.

Water-closets.—It is probable that there is nothing more satisfactory than a good water-closet properly connected with a well-ventilated sewer; but unfortunately such are not universally present in houses. The essential features of a good water-closet are, a basin of some non-absorbent material and of such a shape and capacity as will contain sufficient water as to allow the excreta to fall direct into the water in the basin without touching the sides. There may be said to be five distinct types of water-closet now in general use; they are, the *pan* or *container closet*, the *long hopper*, the *valve* or *plug closet*, the *wash-out closet*, and the *short hopper* or *wash-down closet*.

The first two of these, now generally recognized as being distinctly bad forms of water-closet, are getting so rapidly replaced by better kinds that soon they will become historical curiosities. The pan or container closet is the most objectionable,

and is now prohibited by the model bye-laws of the Local Government Board to be fixed in any new water-closet. Its peculiar feature is the presence of a metal container or pan, which not only rapidly fouls and wears out, but which each time the basin is emptied allows foul air to escape. Very commonly associated with this kind of closet is a D-trap, a contrivance primarily intended, by means of the water which remains in it, to prevent the return and escape of sewer gas back into the house, but which more often becomes filthy by the retention of a large amount of offensive matter. A diagram of this closet is shown in Fig. 40.

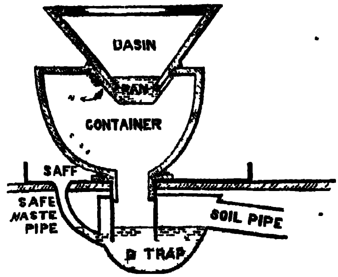


Fig. 40.—Pan closet.

The long hopper is nothing more than a deep conical basin ending in a bent tube or siphon-trap, and which from its shape and construction is extremely liable to become filthy by fouling of its sides. The valve or plug-closet (Fig. 41) was a distinct improvement on the two preceding forms; but in recent years has been quite superseded by other and better kinds. Its chief faults were that it was complicated, its plug or valve often leaked, and failed to keep a supply of water always in the basin, while at the same time it was frequently difficult to keep clean; another defect was that, if by chance the siphon-trap became unsealed, foul air could escape up into the house from the soil pipe through the overflow pipe.

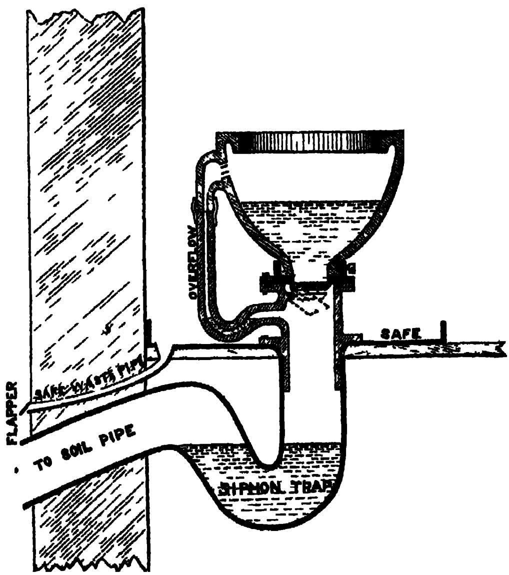


Fig. 41.—Valve water closet.

Of the modern forms of water-closet, the best kinds are the wash-out, and the short hopper or wash-down closets. Both of them are entirely made out of a single piece of glazed earthenware, or at most of two pieces cemented together, and present a minimum amount of surface between the basin and the trap. In the wash-out closet (Fig. 42), a certain amount of water is kept in the basin by means of a dam or ridge, over which the excreta are carried by a flush of water. In some varieties of this closet, the ridge is made too high, with the result that, unless the flush be good, the contents are not at once carried away. Of the short hopper or wash-down class (Fig. 43), one of the best is the "Deluge," which, like all good closets, should be and is provided with a flushing rim, from which the water flows in such a manner and direction that the basin is kept constantly clean.

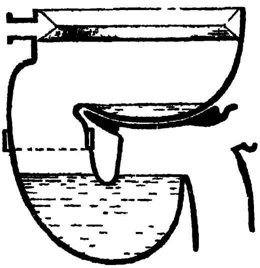


FIG. 42.—"Wash-out" closet.

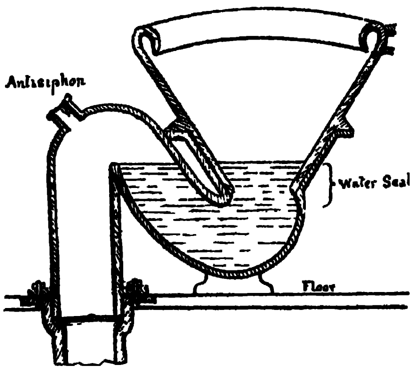


FIG. 43.—"Wash-down" closet.

The quantity of this flushing water available should be at least 3 gallons, and to avoid waste should not exceed $3\frac{1}{2}$ gallons. It should be delivered by a $1\frac{1}{4}$-inch pipe from a height of 5 to 6 feet to secure sufficient force for properly washing out the basin. In some modern types of closet, the placing of the flushing cistern close to the level of the top of the basin has been adopted with success. At first it was thought that the cistern would not flush the basin and clear out the trap so well as an elevated overhead cistern, but experience has shown this to be fallacious, as the provision of a larger inlet to the basin more than compensates for the want of height. A great advantage of these closets (Fig. 44) is that they are more silent in action than the ordinary wash-down water-closet with cistern fixed 6 to 8 feet above the closet basin. This flushing water for the closets should be supplied from its own separate cistern, and not from a cistern or service

pipe which supplies water for general household purposes. Numerous instances are known, showing that outbreaks of disease, such as sore throats and enteric fever, have resulted from supplying water-closets with water direct from mains or from cisterns common to all the needs of a house, the special danger or risk lying in the fact that foul air from the closet basin tends to escape up the usually empty delivery pipe and be absorbed by the water in the cistern. The cisterns for the storage of water for closets are usually of iron, fitted with a ball-cock and valve to regulate the admission of water from the main supply, and provided with an overflow pipe. This overflow pipe should discharge direct through the wall into the outer air a few inches from the brickwork; it should under no circumstances be allowed to discharge into any pipe connected with closets. In cases where water-closets are placed in the upper floors of houses, a lead tray is frequently found placed beneath the apparatus to prevent any overflow from the closet in case of leakage from soaking into the floor and through the ceiling below. This tray is commonly called a "safe," and is of course provided with a waste or overflow pipe carried straight through the wall to end in the open air, and in no way connected with any part of the water-closet apparatus. The placing of a "safe" beneath a closet was frequently needed when the closets used were the old pan and valve water-closets; with the more modern and simpler arrangements the need does not exist, while, too, the old custom of boxing in the apparatus by means of woodwork is now regarded as unnecessary and more or less uncleanly.

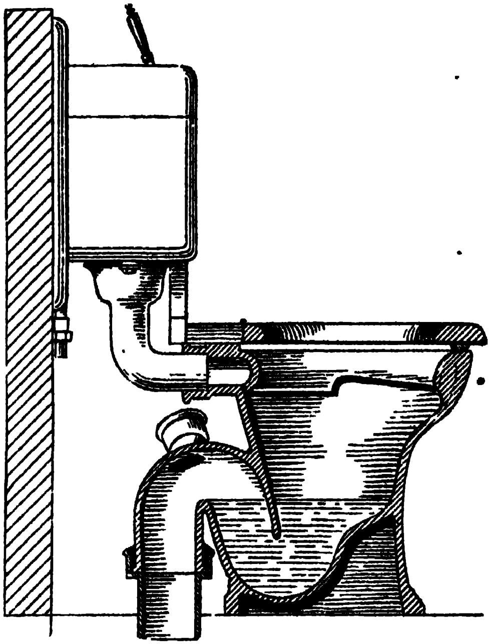


FIG. 44.—The "Silent" closet (Shanks).

A recent development is the siphonic action water-closet, as shown in Fig. 45. In it the service pipe from the cistern has two connections to the closet, one to the basin in the usual manner, the other to the top of the long leg of the siphon. The flush is then divided into two streams, one of which flushes the basin, the other rushes down the siphon, expelling the air through the puff-pipe; this starts the siphonic action, and empties the basin, which is refilled with clean water by an after-flush arrangement in the cistern. Closets of this type are simple and efficient, free from mechanism, automatic in action, and provided with a good depth of water-seal.

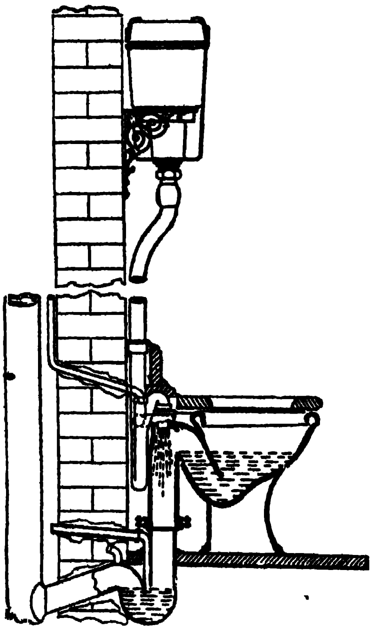


FIG 45.—"Siphonic" closet (Jennings).

The contents of a water-closet should be at once conveyed by a suitable pipe called a soil-pipe, not less than 4 inches in diameter, in as direct a manner possible through the house wall to the outside. To prevent air or gas returning into the house from the soil-pipe, and to completely disconnect it as far as possible, it is usual and necessary to bend the pipe, or even the terminal portion of the closet basin, into the form of an S, an arrangement which retains water and thereby prevents gas from passing back. The essential point about this artifice, commonly called a "trap," is that the bend be sufficiently great as to place some portion of the roof of the pipe below the water-level, and the difference between the water level and the pipe-roof constitutes the *seal* of the trap; to be at all effectual, a water-seal in a trap should be not less than $1\frac{1}{2}$ inches deep. Though there are various other forms of traps, as will be seen later, practically the most useful form in connection with water-closets is the S or siphon-trap. Now, like traps in other situations, those belonging to water-closets are liable to become unsealed by a great rush or volume of water passing into them, and emptying them of their safety water by what is known as siphon action. This is particularly liable to take place when

two or more water-closets discharge into the same soil-pipe, with the result that the discharge from one sucks out water from the traps of the others. This accident can be best prevented by placing an anti-siphon vent in the crown or top of the trap, as shown in Fig. 43, and particularly in the case of a series of water-closets ranged one above another, and discharging into the same soil-pipe, by causing the ventilating pipe or vent from the trap of the lowest water-closet to join or receive, as it were, the ventilating pipe of each trap above, and the whole to be finally connected with the soil-pipe above the highest closet.

The various conduits or pipes within a house, and which run from either sinks or closets to the drain outside the house, are conveniently called "house-pipes." These house-pipes are made of either iron, lead, zinc, or of earthenware; those made of cast iron are the best, and should be so laid that an inspection of them can be easily made. No pipe conveying house refuse or sewage should be allowed to pass under a building unless no other means of construction is possible; in which case it must be laid in as direct and straight a line as can be obtained, and moreover be embedded in concrete 6 inches thick all round, laid at a depth below the surface at least equal to its own diameter, and finally ventilated at each end of the portion beneath the building. Some builders are extremely anxious to conceal pipes, particularly inside walls and under floors; such methods are not only bad, but very risky in case of leakage; in all cases it is infinitely better to run pipes at once by the nearest way through the wall to the outside of the house, where it can join the proper drain.

The majority of houses now built for the upper and middle classes contain baths and bath-rooms. No bath-room should open out of bedrooms unless used exclusively by that bedroom's occupants. The best place for a bath-room is at the side of the house, so that its waste water can be readily carried away outside. The custom of placing a bath in a water-closet is bad, as it not only makes the water-closet useless to the rest of the household when the bath is occupied, but it further causes the bather to breathe foul air if any imperfection exist in the closet fittings. Like closets, bath-rooms need to be well ventilated, and their walls and floors covered with some impervious material; for these floors ordinary oil-cloth or linoleum is as good as anything.

Although the shape and material of which a sink is made are not of great moment, still the construction and destination of its waste pipe are of importance. Formerly the plan was simply to carry all sink-pipes directly into the soil-pipe. The consequence was that foul smells and gases often came up through them rendering houses both offensive and unhealthy. It is now

recognized that the only proper and safe plan is to take care that no pipes whatever join the drain except the soil-pipe of the water-closet. All other pipes carrying slop or waste water ought to deliver freely into the open air above a grating which covers the trap leading to the drain. All sink pipes need to be provided with a trap to collect the grease which forms so large a part of the refuse water sent down from scullery or kitchen sinks. The common bell-trap, so often met with in sinks, is really of little use except for partially preventing solid matter passing down and choking the pipe.

Slop-Closets.—In some towns, particularly in Lancashire and Yorkshire, where a sufficient water supply is not available, or precluded by financial reasons from being utilized for flushing and washing out water-closets, advantage is taken of the household waste water to do this necessary cleansing. Closets from which the contents are removed by the slops or refuse liquids of the household, instead of by clean water supplied for that purpose, are called slop-closets. Of these there are two kinds, namely, those in which the waste is allowed to run directly into the basin, or is poured down by hand; and those in which, with a view to give a better flush, the waste liquid is held up or collected in a suitable contrivance, and then discharged from time to time in a sudden forcible stream; these latter are distinguished by the name of "automatic slop-closets." The general arrangement of these slop-closets will be readily gathered from Fig. 46. The objection to these closets is that the force or stream of water is often insufficient to keep them clean; also the closet basin is apt to get fouled at the back and sides by excrement falling against it, besides which improper substances are readily thrown down it and block the pipes. To get these closets to work well, a fall of at least 5 feet to the sewer is necessary.

Another form of slop-closet, is that in which either a siphon, cistern, or tipper is used to collect the slop-water, and then discharge it in a sudden flush. Experience indicates that the tipper is preferable to the siphon tank, as the latter often will not act owing to clogging with greasy water. A number of closets can be placed on one drain, a single trap serving for the whole, this being placed at the bottom of a manhole for convenience of access; a ventilation shaft is provided at the upper end.

An improvement and development of these closets are the various kinds of automatic slop-closet, in which the slow and uncertain trickle of the slop-water from the sinks is replaced by a sudden gush of the slop-water after storage in either a siphon, cistern, or a tipper. The tipper is merely a metal vessel, so shaped and balanced on pivots that when full the weight of the

contained liquid overbalances it, and causes its contents to be suddenly poured down the pipe. As already stated, siphon-cisterns are unsuited for the storage of dirty or greasy water; so that practically the tipper is the best contrivance for this purpose. There are several varieties of these automatic slop-closets; in some the tipper is placed close to the sink discharge-pipe (top flushing), in others the tipper is placed well away from the slop-stone, and more or less in a piece with the lowest section of the closet-shaft (bottom flushing). The device as to these closets is mainly a question of suitability to any particular place. The tippers, to be effectual, must contain at least three gallons of

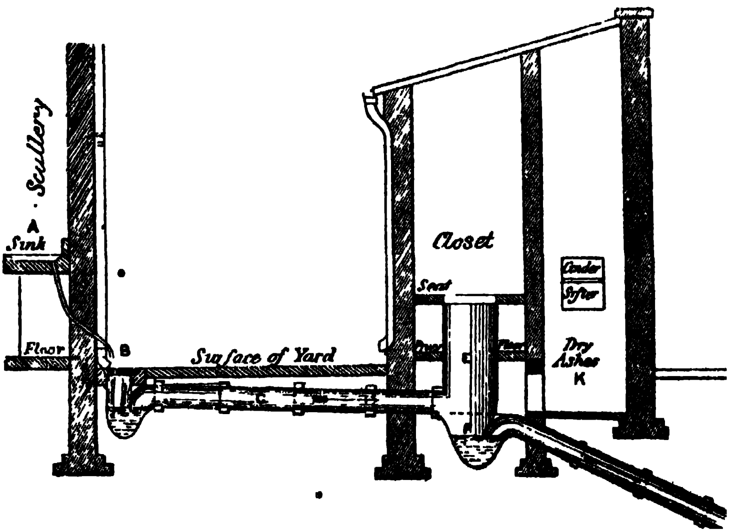


FIG. 46.—Fowler's slop-closet

water for single closets, and five gallons if flushing two or more closets in a row. Some kinds do not have a self-acting tipper, but one discharged by pulling up a handle. Others have the tipper situated at the side or back of the closet-basin. The various automatic slop-closets appear to be advantageous in that their original cost is small, they consume less water, produce less sewage, and, too, are less apt to either freeze or get out of order than the ordinary water-closets; against them are the facts that they are unsightly, less cleanly than water-closets, owing to fouling and lodgment of excreta on the sides. Their use can only be recommended out-of-doors, and when the sewers have a good fall

and a public service of water is laid on to each house. It is also important that each house should have a separate closet. Subject to these conditions, these slop-closets may be of great use and value in towns and suburbs, especially when it is desirable to economize the water.

Trough-Closets are those in which a long metal trough filled with water passes beneath the seats of a number of closets placed side by side, and receives the excreta from them. From time to time these troughs are flushed out by the discharge of a volume of water either by an attendant, or automatically by a siphon-cistern or tilting receiver, and the contents carried away to the sewer through a trap at the end of the trough. These closets are adapted for schools, factories, and groups of artisans' houses, being little liable to get damaged by rough usage or get out of order: the only desideratum being a good large drain well jointed with cement, and plenty of water. Their drawbacks are, original cost, the large quantity of water used, and the alarming noise and splashing which results if the flushing happens to take place when the seat is in use. Trough-closets, whether automatic or otherwise, can only be used where good drains exist and a supply of water is laid on.

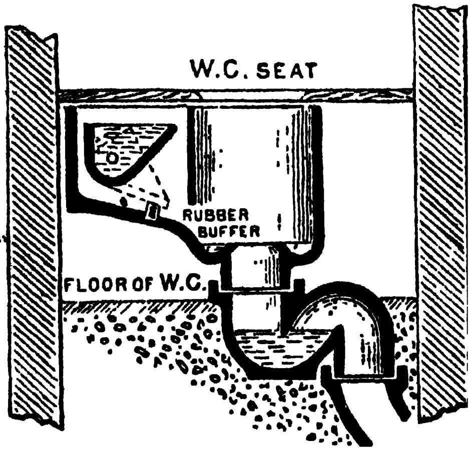


FIG. 47.—Duckett's Blackburn closet.

Middens.—In places where no facilities exist for the use of any of the various kinds of water-closets, recourse has to be had to some dry method of removing excreta from the house. This embraces such arrangements as middens, or privies, and pail-closets, whether used with ashes, charcoal, or earth. The institution of middens, or the setting aside of some spot for depositing filth and refuse, though a most objectionable and insanitary arrangement, was probably a great advance on the more primitive method of depositing everything anyhow and anywhere. Objectionable as they are, it is unfortunately a fact that middens or privies in some form or other exist still, not only in rural districts, but in certain

towns, the essential principle in all being an attempt to both dry and deodorize excreta and refuse by an admixture with ashes. The original midden, if not a heap of decomposing filth, was at best but a hole dug in the ground more or less full of rotting matter, and giving rise to most offensive gases and liquids, which only too readily polluted both the soil around houses and the wells near them. In the present day, where middens do remain, their existence is subject to certain definite rules and conditions; these are briefly as follows. The midden or privy must be at least 6 feet away from any dwelling, and 50 feet away from any well, spring, or stream; ready means of access must be provided for the scavenger, so that the contents need not be carried through a dwelling; the privy must be roofed to keep out the rain, and be provided with ventilating apertures as near the top as possible; that part of the floor which is not under the seat must not be less than 6 inches above the level of the adjoining ground, and moreover be flagged or paved with hard tiles having an inclination towards the door of the privy of one-half inch to the foot, so that liquids spilt upon it may run down outside, and not find their way into the receptacle under the seat; the size or capacity of this receptacle may not exceed 8 cubic feet, by which limitation a weekly removal of its contents is necessitated; the sides and floor of this receptacle must be of some impermeable material, the floor being at least 3 inches above the adjoining ground-level; the seat of the privy should be hinged so as to allow of the ashes being readily thrown in, and the receptacle unconnected with any drain or sewer. Constructed and maintained under these conditions, it is probable that the risks of fouling either soils or wells are reduced considerably; while the pollution of the air is safeguarded to a large degree by the maintenance of the contents in a dry and inodorous condition. But depending as does the success of these middens upon sanitary supervision and scavenging, it is universally acknowledged that any form of them is unadvisable, no matter how well constructed and supervised.

The various forms of **Tub and Pail Closets** are really nothing more than miniature middens, in which the ashpit is represented by a movable receptacle, such as tub or pail, placed under the seat for the reception of the excreta. It is claimed for these closets that the filth removal is much easier and the air pollution less than when midden contents are removed. The pails, whether of wood or of galvanized iron, should have close-fitting lids, and be both air and water-tight. The structure of the closet in which pails are used should be similar to that proposed for middens. The pail or tub should be removed not less often than once a

week, and a clean one substituted for it. To avoid unhealthy smells it is most important that the contents of the pails (urine and fæces) should be kept as dry as possible. This can only be effected by adding to the contents some dry and absorbent material such as ashes, charcoal, earth, or even lining the pail with some absorbent substance such as sawdust or peat. If the mixed urine and fæces be left to themselves in the pails, they rapidly undergo decomposition, but in this state they have a higher commercial value as manure than if mixed with ashes, charcoal, or earth. Various modifications in this respect are in use in various towns; thus in some not only ashes, but all other household refuse is added to the pail, while in others the pails only receive excreta. The presence of the urine tends much to increase decomposition, but its separation is not only practically difficult, but an actual loss of fertilizing material if intended for manure. In Manchester only the fine ashes after sifting are allowed to fall into the pails; while in Halifax, what is called the Goux system was at one time in use, the pail being lined with a layer of peat, or a mixture of tan, sawdust, and soot, substances which render the contents drier and less offensive. Sifted house cinders and ashes form very efficient deodorizers and desiccators, and being always found on the premises of any house are more readily usable than either charcoal or earth. Both these latter substances are also used in pail-closets. In Stanford's closet the charcoal used is prepared from seaweed, about ½ lb. being used each time. Neither ashes nor charcoal have the same beneficial and disintegrating action on the excreta that dry earth has. For this reason, earth-closets have had in one place and another a very extensive trial. About 1½ lb. of clean dry earth is thrown upon the pail contents, either automatically from a hopper, or by hand every time the closet is used. The best kinds of earth for the purpose are loamy surface soil, vegetable mould, dry clay, or brick earth. Chalk, gravel, and sand are not suitable. Care has to be taken that the earth stored is sifted and dry, and that each particular stool is covered at once with the earth, and no slop-water added to the pail contents. Earth-closets are practically the only form of closet used throughout the whole of India, where, on the whole, they work extremely well. If a pail-closet is going to be used at all, from a sanitary point of view the earth-closet is the best form, as, if properly managed, the closet is free from smell, and the process of removing the contents not offensive. In addition to this, the earth is readily obtainable, and not without value as an application to both fields and gardens.

As regards any question which might arise as to which kind

of closet should be placed in any particular house or group of houses, the answer would depend entirely upon the circumstances of the case. Middens, being contrary to all sound principles of hygiene, should in no case be adopted when facilities exist for any other arrangement. For the better class of houses, water-closets or earth-closets are best suited in the country, and water-closets alone in towns. For houses occupied by the artisan class in towns, it is probable that slop water-closets are preferable to pail-closets. The experience of towns where these latter have been in long use goes to show that they are expensive to work, and that the ashes and other dry refuse are so difficult to dispose of as manure, that much of them has to be got rid of by burning in destructor furnaces, a process which the presence of excrement renders more difficult. These are circumstances which render it desirable to separate, as far as possible, the excrement from the solid refuse of the town, and remove it rapidly by the increased facilities afforded by the now very general development and maintenance of public water supplies and sewers. For mills, factories, and schools, trough-closets are undoubtedly the best.

In towns and places where either water-closets in some form or other, or pail-closets for excreta alone, are in use, arrangements must be made for the removal of ashes and kitchen refuse separately. Inasmuch as these can only be removed at intervals from the houses where they accumulate, it is important that they be so stored as to remain free from offence while still on the premises. The articles most likely to become offensive are organic matters, particularly kitchen refuse. In all properly conducted households, these are invariably burnt in the kitchen fire, while only the indestructible matter is placed with the dust and ashes. This practice should be invariably carried out in all dwellings and families. Formerly, the receptacles for ashes and house refuse were dust-bins constructed of brickwork, leaning upon a yard-wall, or against the side of the house, with a wooden cover and a door at the side or front for the removal of contents. This faulty arrangement rendered the contents of the dust-bin extremely liable to become wet from rain, resulting in steady decomposition of the organic refuse with the production of much offensive gas and smell. So glaring were the defects of this system that it has become largely replaced by the provision to each house of small covered tubs or galvanized iron pails or boxes placed in an out-house or yard, and regularly emptied at short intervals. In some places, especially for large establishments, large water-tight bins or so-called dry ashpits are used, the contents being removed at less frequent intervals.

The more detailed account of the ultimate disposal of the

contents of water-closets, pail-closets, and dust-bins is given in the succeeding chapter.

Schools.—It is a remarkable fact that, up to within the last few years, the hygiene of schools and school-houses has received but a small amount of attention. The general principles laid down in the preceding pages as to site, surroundings, construction, and drainage of ordinary dwelling-houses, apply equally to schools. Schools may roughly be divided into three great groups: (1) those under State or public control, such as Elementary Schools and those in Poor-law institutions; (2) the large residential schools and colleges for the upper, middle, and lower classes throughout the country, usually under the control of nominated or elected governors; (3) private schools or colleges, more or less conducted by irresponsible teachers or proprietors. In regard to the schools included within the first two groups, considerable supervision is exercised with reference to questions concerning the health of the scholars as a result of the actions of officials of the Board of Education, Municipal Corporations, County Councils, the Local Government Board, and the Association of Medical Officers of Schools. But, in the case of the purely private schools, there practically exists no controlling authority as to their arrangements and construction. The chief hygienic defect in the arrangement of all schools appears to consist in the undue aggregation of the children. Oddly enough, this is notably so in those schools which come under the inspection of the State, or in respect of which there is a grant of money calculated upon the number of children and the degree of education attained. This tendency to overcrowding in schools lowers the general health standard of the scholars, fosters any liability to disease that may exist in the individual children, and, at the same time, promotes the spread of any communicable or infectious complaint that may be introduced among them.

In a recent circular laying down the principles to be observed in planning and fitting new buildings for public elementary schools, the Board of Education are of opinion that, for large schools accommodating from 300 to 500 places, the most suitable plan is that of a central hall with from seven to ten class-rooms grouped round it. For small schools, a schoolroom with one or more class-rooms will be sufficient, but there should be always at least one class-room, except in special cases. Where the site is sufficiently large, open, and fairly level, the most economical plan is that in which all the rooms are on the ground floor, but circumstances may compel the building to have three floors, but it is desirable that a public elementary school should be on not more than two floors. When there is a central hall it should have a

floor-space of not more than 4 square feet for each scholar for whom the school is recognized. The hall must be fully lighted, warmed, and ventilated. Large schools not built with a central hall must be provided with a wide corridor from 8 to 12 feet wide, giving access to the rooms. The site area may be taken to average a quarter of an acre for every 250 children.

Where a schoolroom is the principal room in a school which has neither central hall nor corridor, it should never be designed for more than 100 children. No schoolroom is desirable which is lighted from one side only. When a school consists of a single room, that room should not contain more than 600 square feet of floor-space. The class-rooms should not be passage-rooms from one part of the building to another, nor from the schoolroom to the play-yard. As a rule, class-rooms should not be planned to accommodate more than 60 nor less than 24 children. In the absence of supplementary light the measurement from the window-wall in a room 14 feet high should not exceed 24 feet 8 inches. When a building is for the use of older scholars, the schoolroom and class-rooms must show an average of not less than 10 square feet of floor-space for each place proposed to be provided; in infant schools, an average of not less than 9 square feet for each place may be accepted. In the higher elementary schools a minimum of 12 square feet per scholar is requisite. In no case should a central hall or corridor be included as counting towards the accommodation available in an elementary public school.

The seats and desks provided in schools should be graduated according to the ages of the scholars, fitted with backs and placed at right angles to the window-wall. An allowance of 18 inches per scholar at each desk and seat will suffice (except in the case of the dual desk), and the length of each group should be therefore some multiple of 18 inches, with gangways of 18 inches between the groups and walls. In the case of the dual desk the usual length is 40 inches, and the gangways 16 inches. In an ordinary class-room five rows of long desks or six rows of dual desks are best, but in rooms providing for more than 60 children, there should not be more than four rows of long desks or five rows of dual desks. Each desk should be inclined at an angle of 15 degrees. Flat desks tend to make children stoop; the edge of the desk, when used for writing, should be vertically over the edge of the seat.

The wall of every room used for teaching must be at least 12 feet high from the floor to the ceiling; if the room-area exceed 360 square feet, the height should be 13 feet; and, if it exceed 600 square feet, then the height of the walls must be at least 14 feet. Roofs open to the apex are undesirable in schools.

The outer walls of all schools should be solid; if of brick, the thickness must be at least one brick and a half, and, if of stone, at least 20 inches; where hollow walls are preferred, the external one must be 9 inches thick, with a $4\frac{1}{2}$-inch lining and a 2-inch cavity. All walls should have a damp-proof course just above the ground-line, and all timber be protected from mortar and cement by asphalt or tar. In all schools, entrances should be separate for each department and each sex, the doors opening outwards as well as inwards. Each department in a school should have its own staircases, separate ones being provided for boys and girls: these staircases should be fireproof, and external to the halls, corridors, or rooms. Triangular or winding stairs are objectionable, each step should be about 13 inches broad and not more than 6 inches high. The provision of proper cloak-rooms in schools is of importance; these should be external to the schoolrooms and class-rooms, also amply lighted and ventilated, and providing separate ingress and egress. The gangways between the hanging-rails should be 4 feet wide, the hat-pegs 12 inches apart, not directly one above the other, numbered, and of two tiers. The lighting of school and class rooms is of vital importance. Where left light is impossible, right light is next best; windows full in the eyes of scholars are objectionable. The sills of the main lighting windows should be placed not more than 4 feet above the floor; the windows should reach nearly to the ceiling, and the upper portion be made to swing inwards. Skylights are particularly objectionable. The ventilation and warming of rooms used for teaching are of paramount importance. There must be ample provision for the continuous inflow of fresh air and for the outflow of foul air. The best way of providing the latter is to build to each room a separate air-chimney, carried up in the same stack with the smoke-flues. An outlet should be by a warm flue or exhaust, otherwise it will often act as a cold inlet. Inlets are best placed in corners of rooms furthest from doors and fireplaces, and should be arranged to discharge upwards into the room. Gratings in floors should never be provided. The ideal temperature for a school or class room is from 56 to 60 degrees. Where possible, this warming should be secured either by means of open fireplaces or by hot-water pipes. Common closed stoves are most undesirable, and should be permitted only when provided with proper chimneys, of such a pattern that they cannot become red hot, are supplied with fresh air, direct from the outside by a flue of not less than 72 inches, superficial, and of such a size or shape as not to interfere with the floor-space necessary for teaching purposes. All fireplaces and stoves need to be protected by guards. As regards sanitary arrangements in

schools, water-closets within the main building are not desirable. They should be at a short distance and completely disconnected from the school. Privies should be fully 20 feet distant. Approaches to all latrines, urinals, or closets must be wholly separate for boys and girls. Every closet should be at least 27 inches wide, fully lighted, ventilated, and supplied with a door 3 inches short at bottom and 6 inches short at top. More than one seat should never be allowed in any closet. The following table shows approximately the number of closets needed in schools:—

	For girls	For boys.	For infants.	For girls and infants.
Under 30 children . . .	2	1	2	2
" 70 " . .	4	2	3	4
" 100 " . . .	5	3	4	5
" 150 " . .	6	3	5	6
" 200 " . .	8	4	6	7
" 300 " . . .	12	5	8	8

In boys' schools the urinal accommodation should be in the proportion of 10 feet per 100 boys. Earth or ash closets, if of an approved type, may be employed in rural schools, but drains for the disposal of slop and surface water are necessary. Cesspits and privies should be permitted only where unavoidable; these should be at least 20 feet from the school.

Hospitals.—All that has been said in respect of site, surroundings, and construction of houses and schools applies with still greater force to hospitals. As charitable institutions, existing for the purpose of affording medical and surgical aid to the sick poor, hospitals, on economical grounds, have largely to be so constructed that the patients may be grouped together in general wards. It is this aggregating of large numbers of sick or diseased persons under one building that constitutes the most important factor in hospital hygiene. It has long been known that overcrowding in the wards of hospitals is productive of the worst results, particularly in surgical wards, where the neglect of proper sanitary measures produces the class of diseases known as "septic," of which well-known forms are erysipelas and blood-poisoning. Bearing this fact in mind, we are able to understand that the chief conditions to be avoided in all hospitals are: (1) insufficiency of cubic space; (2) inefficient ventilation; (3) improper arrangements for the removal of excreta, refuse, soiled linen, dressings, poultices, etc.; (4) faulty arrangements of the buildings.

Insufficiency of cubic space and inefficiency of ventilation go together; in fact, mere cubic space of itself is of little value, unless accompanied by adequate ventilation. As a general rule, it may be said that large wards are more readily ventilated, warmed, and managed than small ones. The most general form of hospital wards is rectangular; but in a few hospitals they are circular; and in the John Hopkins Hospital, Baltimore, there are octagonal wards. The dimensions of wards are dependent upon the number of patients to be accommodated and the amount of cubic space to be allotted to each. Rectangular wards vary from 24 to 30 feet in width, 13 to 14 feet in height, and from 30 to over 100 feet in length. As regards space, it is considered that each patient should have from 100 to 120 square feet of floor area, and from 1500 to 2000 cubic feet of air space. For fever, severe surgical, or lying-in cases, the requirements are greater, being about 3000 cubic feet of air space and 140 square feet of floor area. Experience shows that nursing is best carried out when the number of beds in a ward do not exceed thirty or thirty-two. These beds are best arranged with their heads to the wall and facing into the ward. Each bed should be placed between two windows, or, at most, two beds in between two windows. The windows ought to be opposite one another, and should extend from 3 feet above the floor to within 6 inches of the ceiling; they should all be capable of being opened at their upper parts. One square foot of window may be provided for every 80 cubic feet of space in the ward. The heating of hospital wards may be effected by open fireplaces or ventilating stoves, or both, or by hot-water pipes. The temperature of wards is best kept at 60° F. To secure adequate ventilation, the air is best warmed before passing into the wards. This may be done either by means of ventilating stoves, Galton's grates, or by coils of hot pipes at inlets placed beneath the heads of the beds. Extraction of foul air is provided by fireplaces, stoves, windows open at the top, or by special shafts. In some infectious hospitals, such extraction shafts are made to lead to a furnace, the heat of which serves both as a means of extraction and a means of destroying any germs which may be in the outgoing air. It is needless, perhaps, to say that the floors should be impervious, free from crevices, and polished; the walls ought to be lined with tiles, cement, or glazed brick; or, failing these materials, simply painted. The junction of floor and the walls may be made round, so that dust can be easily seen and removed.

Circular wards for hospitals were first advocated in this country by the late Professor Marshall, in 1878; the advantages claimed for them being: (1) freedom of frontage to all points of

the compass, and, consequently, greater accessibility to both light and air; (2) greater area contained within a given length of wall; (3) greater facilities for administration and cleanliness. For many years this idea of circular wards received much opposition, more particularly from architects, on the plea that they would be very expensive to build. Circular wards now exist in various hospitals, both in this country and on the Continent, notably at Antwerp, Greenwich, Burnley, Liverpool, Hastings, and Milton near Gravesend.

The need for speedy removal of all excreta and refuse is of paramount importance in hospitals, as in private buildings; the principles to be adopted are the same as have already been explained.

As regards the faulty arrangement of hospital buildings, the chief defect usually met with is the absence of effective separation of the wards from the other parts, with due regard to economy of construction. The precise disposition of the several parts of a hospital in relation to each other, of necessity greatly depends on the size of the hospital and on the shape and area of the site; but the really essential principles which should guide us in constructing a hospital are, briefly: (1) an avoidance of all intimate connection between the wards and the administration buildings; (2) separation of medical from surgical wards; (3) complete atmospheric disconnection between the wards on the one hand, and the mortuary, laundry, and out-patient department on the other (Keith Young).

To secure these results, the most common plan now is to build hospitals upon what is called the pavilion system. This system is merely the arranging, on a plot of ground, of a series of one, two, or more storey buildings, called pavilions, and connecting them together by corridors or covered ways. The individual pavilions or blocks of buildings may be of any shape or size, as, for instance, in the new Great Northern Central Hospital, London, where, although there are both circular and oblong wards, they are all practically isolated from each other and from the rest of the hospital. Care should be taken to see that the various buildings are not so close to each other as to seriously interfere with the free circulation of air, or shut out light. A good rule to adopt is, if of two buildings one is higher than the other, the distance between them must be equal to the height of the higher; if two buildings are of the same height, then the distance must be one-and-a-half times the height.

Besides ordinary or General Hospitals, there are a number of what may be called Special Hospitals. Among these latter are such hospitals as those for diseases of the eye, ear, or throat;

those for consumption, for children, for convalescents, for cancer or incurables, for lying-in women, and, finally, those for infectious diseases. Although in all matters of structural hygiene these hospitals require the same care as the ordinary hospitals, still, in addition, they present some special needs. Thus, ophthalmic hospitals need the removal of sharp angles in wards against which blind or partially blind persons may accidentally injure themselves, and the provision of handrails on both sides of staircases. Open fireplaces are a mistake in these hospitals, as often the flickering flame of a fire is both trying and injurious to diseased eyes. Consumption hospitals require special warming and ventilation arrangements for their inmates, as well as liberal provision for those able to get up and move about. The most prominent need in all children's hospitals is an isolation ward, as young children are extremely susceptible to infectious diseases. Convalescent hospitals are more properly homes for those recovering from acute illness, rather than mere hospitals for the sick. In the same way, cancer and incurable hospitals need to conform more to the freedom and independence of home life than to the more rigid arrangements of the institutions for treating acute cases. Lying-in hospitals, from the peculiar nature of the cases they receive, should be constructed with small rooms and not with large wards. Every such hospital should be provided with an isolation ward, absolutely distinct from the rest of the building.

Isolation, or infectious hospitals, are quite a class by themselves; they may be either permanent or temporary buildings. Reference has already been made to the need, in these hospitals, of greater cubic space and ventilation. Owing to the remarkable tendency to aerial spread of infection in the diseases taken to infectious hospitals, the communication with the outside world has here to be kept under the strictest control and each disease isolated separately, and kept, if possible, in separate blocks or buildings, the communication between which should be absolutely forbidden. Each block, besides wards, closets, bathrooms, and sinks, should have linen, store, and fuel rooms, as well as a nurse's room. The disinfecting chamber, mortuary, and stables for ambulances and horses, should also be clearly disconnected from all other parts of the building.

Considerable controversy has taken place whether infectious or isolation hospitals should be permanent buildings or merely temporary ones. The truth probably lies in the view that all administrative arrangements, and a certain limited accommodation for the infectious sick, should be in permanent buildings, which existing thus ready to hand in non-epidemic times can be quickly supplemented by additional wards in either huts or tents within

a few days, in case of widespread epidemics. Some means of isolation are needed in every community at all times, and it is a sounder policy to be able to delay and prevent epidemic outbreaks by isolating the few sporadic cases as they occur, in a small but permanent infectious-disease hospital, than have to grapple with epidemics already in full existence by means of hastily constructed, expensive, and often costly temporary structures. Many materials have been suggested for the construction of these temporary buildings, more particularly wood, galvanized iron, canvas, and waterproof paper. Although they are comparatively cheap and rapidly erected, temporary hospitals should never be regarded as able to supersede permanent buildings of brick or stone; their true use is to supplement, not to supersede. Moreover, they are extremely difficult to ventilate and to warm in winter or cool in summer. Their durability is small, and their proper disinfection is almost impossible. Of course they can be burnt when done with; but if epidemics of infectious disease rapidly succeed each other, the renewals of temporary hospital buildings will soon exceed the cost of structures of a more permanent nature. As infectious hospitals, unlike the great bulk of general and special hospitals, are in no sense charitable institutions, but really public buildings provided and supported by rates, the true bearing and merits of the question whether these hospitals should be temporary or permanent buildings is one which intimately concerns the interests of every citizen.

CHAPTER V.

THE ULTIMATE DISPOSAL OF REFUSE AND EXCRETA.

Disposal of House and Town Refuse.—The simplest method is to burn the contents of dustbins and ashpits, which consist of dry refuse, paper, rags, and other more or less combustible material, and subsequently bury it in the ground. Animal and vegetable refuse may also be dealt with in this way, and, if covered or mixed with ashes, its combustion can be secured slowly without any offensive odours being given off. This simple procedure is, however, only possible in the case of more or less isolated houses in country districts; in towns and other populated areas it is quite impracticable—in fact, the effective disposal of civic waste constitutes one of the greatest difficulties which every sanitary authority has

to face. The difficulty is further increased by the fact that the material to be dealt with varies in quality and quantity according to the season, the kind of fuel used, and the habits of the people. The magnitude of this problem of refuse disposal is apparent when we realize that, for urban areas, the quantity of ashbin refuse averages from 240 to 260 tons annually for each 1000 inhabitants. Much of this might be obviated if individual householders would burn in their own grates such materials as bits of paper, rags, potato peelings, cabbage leaves, and similar substances. Few, however, do so, with the result that the average dustbin contains an objectionable amount of readily decomposable material, which, unless rapidly and effectively removed, conduces soon to become an actual and serious menace to health.

The removal of house refuse, in most towns, is carried out weekly, while in a few places removal twice or thrice a week is secured. A daily removal is most desirable, as decomposition and its attendant dangers are thereby reduced to a minimum. What becomes of this refuse matter varies according to local circumstances, but in all cases it should be conveyed through the streets in covered carts only. In some places, this dustbin refuse is used for the filling in of pits and excavations, or for raising the level of low-lying land preparatory for utilization as building sites; this is a most pernicious practice, and should be discouraged in every way. An alternative procedure is to sift and sort the refuse at a depôt. The cinders and coal, along with the fine ashes, are sold to brickmakers as "breeze;" the clinkers, broken crockery, etc., or "hard core," is used for road-making; and the "soft core," consisting of vegetable and animal refuse, is sold for manure. The remaining substances, such as scraps of iron, tin, paper, bottles, rags, and corks, are separated out and sold. This process is not commendable, mainly owing to its disgusting nature and liability to unfavourably affect the health of those engaged in sorting and sifting. A third and more usual method is to burn all house and street refuse in special furnaces or destructors, which destroy all combustible substances, leaving as a residuum a mass of hard material, called clinkers, which may subsequently be utilized for road-making or ground down and mixed with lime to form cement. In certain places, the steam generated from boilers connected with these furnaces is utilized for electric lighting, traction, water or sewage pumping, and other forms of useful work. Hitherto, the evaporation of 1 lb. of water per pound of refuse burned has been considered a good result, but with modern furnaces an average evaporation of 1·43 lb. of water can be obtained.

The object of every destructor is to convert the refuse into

fixed and harmless products by means of combustion, and the transformation of organic matter into innocuous forms of vapour, carbon dioxide, and nitrogen. Many types of destructor have been designed, but those which have stood the test of experience may be divided into two classes: (1) natural draught low-temperature furnaces; (2) forced draught high temperature furnaces. The former class are represented by furnaces of the Fryer type, in which a series of cells are arranged back to back. Each cell has a sloping hearth and fire-grate, with top opening at the back for the admission of refuse. Furnace frames and doors are provided for the removal of clinkers; beneath the bars is situated the ashpit, which is practically a reservoir into which the dust and

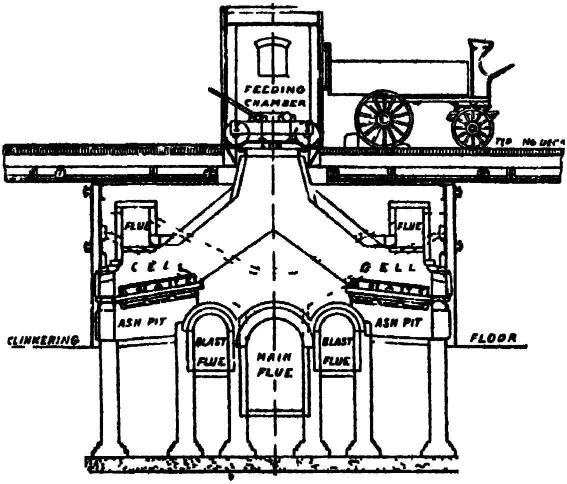


FIG. 58.—Sectional view of a forced draught Refuse Destructor.

fine ash fall. The top of the destructor forms a level platform upon which the refuse is tipped from the carts, and each furnace has a feeding hopper, which discharges by means of a lever worked from above. The employment of forced draught has resulted in the production of high-temperature furnaces, in which the general principles of construction are very similar to those of the Fryer type. In the best modern forced draught, high-temperature destructors the gases enter the boiler chamber at a temperature of 2000° F., and in a well-managed plant the temperature can be maintained at 1600° F. The Horsfall back-to-back type is fitted with forced draught, provided by two patent steam-blowers placed at the end of the blast flues. By the use of these blowers the

temperature in the ashpit is increased to 400° F., the blast being turned off when trimming the fires. In connection with some of these installations, centrifugal dust-catchers have been constructed and also solder extraction furnaces, designed to recover tin and solder from old cans. In the Meldrum destructor the furnace has one continuous grate with four sets of firing-doors, the products of combustion having to pass over the whole range of fires. The ashpit is divided into four closed compartments, each firing-door having its own separate ashpit, in each of which are fixed two blowers which draw their air through the generator. The fires are clinkered from each door in rotation, three fires being always kept charged, and the temperature of the furnaces maintained at incandescence. The gases pass from the combustion chamber through a Lancashire boiler placed in the main flue. The Heenan destructor is similar in many respects to the Meldrum type, the cells being arranged in series, and the gases from each grate deflected to each adjacent grate in turn by an undulating arch.

The average cost of burning refuse in these modern forced draught destructors works out at about 1*s.* 8*d.* in the metropolitan area and 1*s.* a ton in the provinces; but the efficient and economic working of these furnaces depends largely upon supervision and the maintenance of high temperatures, which can be obtained only by continuous feeding. In addition to the regular and proper feeding of the cells, it is necessary for the prevention of nuisance that the fires be stoked regularly and systematically, and that the blast be cut off each time during the clinkering process. Given a good destructor and proper management, civic waste and house refuse is reduced to about one-third of its original bulk, the residue being innocuous clinker, metallic refuse, and dust.

The Nature and Composition of Sewage.—The term "sewage" includes not only human excreta, solid and liquid, but also the waste-water and impurities from houses and factories. From a hygienic point of view, the excreta are the most important constituents, but besides the excreta and household wastes, sewage contains rain and storm-waters, as well as water used in cleansing or sprinkling streets; sewage, therefore, is an extremely complex fluid, varying in the same place from hour to hour both in its volume and in its chemical composition. Although the total amount of excretal matter is greater in sewage where water-closets are in use, yet the average composition of such sewage is no stronger than that from towns where there are no water-closets. The reason for this is that ordinary domestic slop or waste-water is usually a very foul liquid, and that the existence of water-closets means a plentiful water supply, which is sufficient to dilute the sewage to as low a strength as that derived from a non-water-closet

town. The following table gives the average composition of sewage from towns sewered on the water-closet system and that from towns using middens:—

AVERAGE COMPOSITION OF SEWAGE, IN PARTS PER 100,000.

	Total solids in solution	Organic carbon.	Organic nitrogen	Ammonia	Total combined nitrogen	Chlorine.	Suspended matters. Mineral	Organic.	Total
Midden towns	82·4	4·181	1·975	5·435	6·451	11·54	17·81	21·30	39·11
Water-closet towns	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69

The total quantity of sewage depends largely upon the amount of pure water supplied per head per day; in the same manner, the solids in solution in any given sewage vary with the quality of the drinking water.

The Removal of Sewage.—There are two main methods of getting rid of sewage from the dwelling—they are the dry and wet methods. The former has to be employed where tub, pail, and midden closets are in use, the latter where water-closets exist. As to the relative merits of the two methods, no absolute answer can be given in exclusive favour of either. Each is the best under different circumstances. For isolated houses, small villages, and for temporary collections of people, as in camps, the dry method is suitable; its efficient working, however, is dependent upon adequate supervision and the greatest care as to details. Although the initial outlay in closets and sewers is small where the dry method is used, there is the constantly recurring cost of removing the excreta as well as of cleansing the pails, etc.; further, some provision has to be made for carrying off slop-water, some urine, and possibly a certain amount of liquid trade products as well. The chief objection, however, to the system is the fact that the excreta are retained for some time in or about the dwelling, instead of being removed immediately. For these reasons, the water-carriage of sewage is indispensable in towns; its advantages are that it is the cleanest, readiest, and in many cases the cheapest method. The success of this plan depends on there being a good supply of water, properly constructed sewers, with good ventilation and proper outfall and means of disposal of the sewer-water. The quantity of water necessary to flush sewers and maintain them in a healthy state is about 25 gallons per head per day. If rain-water passes in, it flushes the sewers thoroughly

sometimes; but it also carries in gravel and debris, and may burst the sewers in certain cases, to provide against which storm-overflows have to be provided.

The chief sanitary installations connected with a water-carriage system of sewage removal are water-closets, soil-pipes, drains, waste-pipes from baths, sinks, or rain-water gutters and sewers. As the essential features of water-closets have already been explained, we may now consider the other appliances in detail.

Soil-pipes are pipes for immediately carrying away excreta or sewage from the water-closet to the house-drain. Throughout their course they should be observable, and consequently not be built into walls, but preferably carried at once outside through the house-wall, immediately beyond the siphon bend or trap of the closet. Soil-pipes should be made of drawn lead, and of at least 8 lbs. per superficial foot, and all joints be of the kind known as "wiped." Iron pipes may be used, but must be smooth inside, and protected either by Angus Smith's preservative, or coated with a vitreous glaze. In iron pipes the joints must be caulked with lead. A soil-pipe should not be more than 4 inches in diameter, and continued from its highest point well above the roof by a pipe of the same size, without angles or bends, discharging by an open aperture well away from all windows or chimneys.

The connection between the closet-basin and the pipe is often difficult, as the basin is generally made of earthenware and the pipe of metal. Doulton's patent ceramic joint obviates this difficulty, and a perfect union is formed. The "wiped" joint commonly used cannot always be depended on.

Where several closets on different floors discharge into the same soil-pipe, the discharge of water down the soil-pipe may cause unsealing of the traps of the water-closets. This unsiphoning is prevented in the case of the highest closet by the ventilated soil-pipe, but not always so for the lower closets. For these it is desirable to carry a pipe from the highest point of the closet-trap, where it joins the soil-pipe, through the wall into the outer air. Such an anti-siphonage pipe effectually prevents the water being sucked out of the trap of a lower water-closet when the one on a higher floor is being flushed.

The soil-pipe discharges direct into the drain, and at this point it is undesirable to place any trap, as it imposes a useless impediment to the passage to the sewage from the soil-pipe to the drain.

Fig. 49 shows a tier of three water-closets fixed one above another. The upper one is a valve-closet connected to an anti-D trap, with ventilating pipes to trap, and valve-box. The middle

one is a wash-down pedestal water-closet, with a ventilated branch soil-pipe. On the ground floor is a siphonic action water-closet. The whole of the closets are connected to a lead soil-pipe, the branch soil-pipes being fitted with branch ventilating or anti-siphonage pipes. The main soil-pipe is connected by an earthenware rest-bend to the drain, which is supported on a bed of concrete.

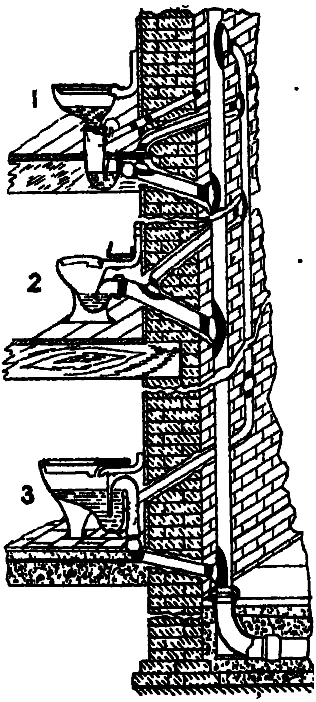


FIG. 49.—Showing soil and anti siphonage pipes (Bennett).

The House-drain receives, ordinarily, not only the discharge from the water-closets by the soil-pipe, but also rain-water, and waste water from baths and sinks. Drains may be made of either earthenware or of iron. They should be laid in straight lines, each pipe being placed with the spigot and not the socket end directed towards the flow of sewage. The usual size of a main house-drain is 6 inches, but branch drains rarely exceed 4 inches in diameter. Their fall should not be less than 1 in 40 or 60. Small drains are more completely self-cleansing than large ones. Earthenware drains should be laid on a bed of concrete at least 6 inches thick, so as to prevent subsidence, and if carried under a house they should be covered with an equal thickness of concrete. Joints should be made with cement, and on no account with clay. Drains made of iron are coming into use; they are certainly preferable to earthenware, as being less liable to fracture, and more readily made water-tight at the joints. Just before the drain leaves the curtilage of a house, and near its junction with the sewer, it should be trapped, and on the house side of this trap an inlet ventilator be provided. This inlet may be placed at the ground-level, or a few feet above the ground. The exit for air entering by this inlet is provided by the upper end of the soil-pipe carried full-bore above the eaves. By this arrangement a complete ventilation of the house-drain is secured, and a free escape of any foul gases directed out-of-doors.

The form of trap intercepting the drain from the sewer is

often of the kind shown in Fig. 50, and not infrequently associated with some form of manhole or inspection chamber. This,

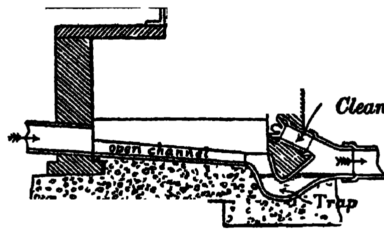


FIG. 50.—Disconnecting manhole.

if close to the house, is provided with an air-tight cover, the inlet ventilator being arranged at some convenient point. The manhole is built of brick set in cement, and in it half-channel pipes convey the sewage instead of complete pipes. Where two or more drains converge to the same point, the location of an inspection chamber or manhole is desirable, as facilitating access and inspection in the event of accidental stopping.

Traps are used as a barrier to prevent the passage of sewer-air into houses. A good trap should completely disconnect the air in one pipe from that in another. This is done by means of a water-seal, which should never be less than to allow the water to stand three-quarters of an inch above the openings. The trap itself should be of such a form as to allow of its being completely washed out with every flush of water passed through it.

Traps are almost of infinite variety, but may be conveniently divided into the *siphon*, the *mid-feather*, the *flap-trap*, and the *ball-trap*.

The *siphon*-trap consists of a curved tube, the curve being full of water, which should stand at least three-quarters of an inch

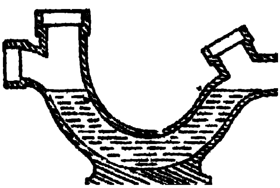


FIG. 51.—Siphon-bend.

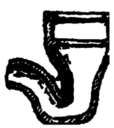


FIG. 52.—Siphon-trap.

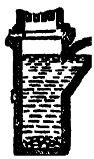


FIG. 53.—Gully-trap.

above the top of the curve. If two siphon-traps succeed each other, one will suck the other dry, unless an air-opening is placed between them; the siphon is the best variety of trap.

A good form of gully-trap for sinks and slop waters is Dean's (Fig. 55), which has a movable bucket for removing deposits.

The *mid-feather* consists of a round or square box, with an entry tube on one side and an exit tube at the same height on

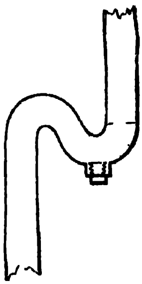


FIG. 54.—Siphon sink-trap with movable screw for cleaning.

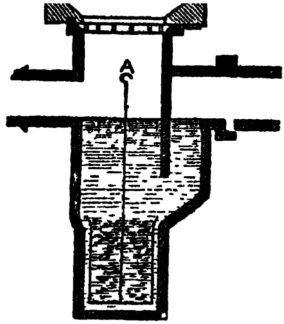


FIG. 55.—Dean's gully-trap. A, handle of movable bucket.

the other; water stands in the trap up to the lower margin of each pipe, and a partition passes down between into the water (Fig. 56). It is a bad form of trap, as it is not self-cleansing, and fails in all the essentials of a good trap; it is also liable to leak under the covering-stone, when the gas readily escapes.

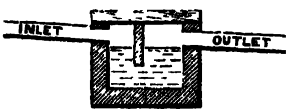


FIG. 56.—Mid-feather-trap.

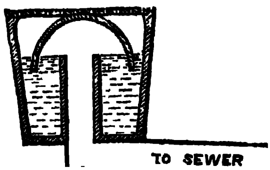


FIG. 57.—Bell-trap.

The *bell-trap* is a modification of the mid-feather principle; it is a very inefficient form of trap, as the bell portion is removable, and when taken off the water-seal is done away with (Fig. 57).

The *flap-trap* is a hinged valve allowing water to pass in one direction: it was expected that this would prevent the reflux of sewer-air, but it has been found to act very imperfectly, and is useless to prevent sewer-gas returning.

The *ball-trap* is one in which a ball rises with the rise of water and closes an orifice; it is a very imperfect form of trap.

Gully-traps should be at least 18 inches from the wall of the house, and their superficial surface should be as small as possible, so as to diminish the evaporation of water.

Siphon-traps, however perfectly made, cannot be relied on to prevent the passage of sewer-air. Water alone cannot always resist the pressure of air, and even if it accomplishes this, it will absorb foul gas from below and emit it above; hence the absolute necessity for the disconnection and the ventilation of the sewers.

Grease-traps may be classed with ordinary gully-traps. They should not generally be used for ordinary kitchen or scullery sinks, but may be necessary when a large amount of grease is passed off, as in hotels, etc. Grease-traps partake of the nature of cesspools, and should not be used when avoidable.

Concerning traps generally, engineers look suspiciously on every one of them, and endeavour to render them unnecessary by thorough ventilation and disconnection of the drains.

The essentials of a good trap are that the water stand at least three-quarters of an inch above the openings, that the trap itself be self-cleansing, and that every portion should be effectually washed out by every flush. A trap is only efficient so long as it contains water: if not in constant use, especially in dry weather, the water evaporates, and direct communication is established with the drain. In dry weather frequent flushing is therefore necessary.

Waste-pipes discharging water from kitchen sinks, sculleries, etc., and bath-waste pipes carrying away water from baths, should not connect directly with any drain, but must discharge into the open air, about 18 inches above a grating covering a good water-trap; they should not be made to open under the grating, as sewer-gas may be sucked up through the pipes by the higher temperature in the house. Waste-pipes should also have a siphon-trap (Fig. 54) with a 3-inch water-seal. They should *not* be connected with any soil-pipe.

To prevent the deposit of grease or sand in the drain-pipe, scullery sinks require to be provided with a grease-intercepting chamber; if grease is allowed to flow into the drain, it may gradually stop up the pipe by adhering to the sides, and is then difficult to remove. This chamber is generally made of hollow stoneware, with a tight iron cover, and ventilated. The hot greasy water from the sink is discharged at the bottom of the chamber, the grease is then cooled and rises to the surface for removal, the sand sinking to the bottom, while the water passes away to the drain. The grease and sand must be removed every second or third day.

Waste-water pipes are best made of lead, and should be sufficiently strong to resist the action of hot and cold water—say about 10 lbs. to the square foot; they are generally 3 inches in diameter.

Rain-water pipes should also discharge their contents over a trapped gully, so as to be completely cut off from the drain.

The Examination of Drains.—In practice this amounts to the application of certain tests for the determination of soundness. Two chief methods of testing drains are in use, namely, by smoke or volatile agents, and by water. The smoke-test consists in filling the drain or soil-pipe with smoke, the assumption being that this will find its way through any leak, faulty joint, or trap, thus indicating the site of the defect. The smoke may be forced into the pipe or drain from a pumping apparatus, or be produced within the drain from a specially prepared grenade or rocket. An alternative procedure is to pour a table-spoonful of oil of peppermint, mixed with hot water, either down the highest water-closet or down the pipe at the highest point available; as this is a very volatile and pungent oil, there is no difficulty in tracing where the odour is emitted, and so detecting the leak. Although convenient for testing traps and fittings above ground, these tests are of little value in the examination of underground pipes. The only absolutely trustworthy test for drains is the water-test. Having plugged up the lower end of the drain by a suitable water-tight stopper, the drain is gradually filled with water. If the water-level remains constant for half an hour or more, the drain may be considered sound and water-tight. If it will not fill, or the level falls rapidly after filling, there is leakage somewhere, and it will be necessary to open it up and repair, or perhaps relay.

In applying the water-test to drains, it must be remembered that each foot of water-head exercises a pressure within the pipe or drain of 0·432 pound on the square inch, or to find the head of water required to obtain any given pressure, this, in pounds per inch, if multiplied by 2·31, will give the head in feet. It is doubtful whether, in the routine examination of drains, a greater head of water than 10 feet need ever be employed. If stoppage of the drain occurs, and there are manholes or access pipes provided, the spot where the obstruction takes place can be easily localized; but if no such arrangement exists, the drain or pipe will have to be broken in one or more places, until the point of stoppage is found. Brisk flushing with water will generally remove any obstruction. Stoppage may be caused from imperfect laying of the drain, from improperly finished-off joints, so that a rough surface is left on the inside of the pipe; or roots of trees may find their way through the joints of earthenware pipes, when clay is used for jointing. The most frequent cause of stoppage, however, is that various articles are improperly thrown down the water-closet, and gradually fill up the pipe.

Sewers are the trunk canals into which the house-drains empty

their contents. Unfortunately, the two terms "drain" and "sewer" have been used loosely and confusedly. By sect. 4 of the Public Health Act, 1875, a "drain" is defined as meaning any drain of and used for the "drainage of one building only," or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed. "Sewer," on the other hand, includes sewers and drains of every description, except drains to which the word "drain" interpreted above applies, and except drains vested in or under the control of any authority having the management of roads and not being a local authority under the Act. From these definitions it follows that where two or more houses have a common drain, that drain is, within the meaning of the Act, a sewer, and as such vested in the local sanitary authority for its proper cleansing, ventilation, and repair, under sects. 13 and 15 of the Public Health Act, 1875. These, however, are not the interpretations which have been placed upon the expressions "drain" and "sewer" in all cases, as the situation is complicated by the Public Health Acts (Amendment) Act of 1890. By sect. 19 of this Act, which, however, is only an adoptive Act, and therefore not in force in every district, we find that where it is in force the definitions of the 1875 Act are considerably modified, so much so that, if two of the houses belong to the same person, the combined drain is a sewer, and repairable as such by the local authority; but if the two houses belong to different owners, then this combined drain is a drain under the Acts, and any expenses of repair are to be borne by the owners in due proportion. The sect. 19 of the 1890 Act speaks of a "single private drain," and the whole difficulty seems to hinge on what this expression really means; it is unfortunate that the Act does not define it. Certainly the judgments in specific cases, given in the Courts, have not rendered the point any clearer. In a recent case[1] it was laid down that where two or more houses are drained by a single pipe, neither the fact that the pipe is wholly situate on private land, nor the fact that the houses belong to different owners, will suffice to make the pipe a "single private drain" within the meaning of sect. 19, so as to entitle the local authority to require the owner (under sect. 41 of the Act of 1875) to amend same.

The verdict of the Court of Appeal in another recent case,[2] being also on the question of the meaning of a "single private drain," under particular circumstances, created a fresh anomaly, and, to a lay mind, appears a curious decision.

[1] *Thompson* v. *Eccles Corporation.*
[2] *Jackson* v. *Wimbledon Urban District Council.*

From this case it appears that the owner of certain houses had been called upon to pay for certain repairs to a pipe which ran in the rear of several houses, and received the drainage of each, but which joined another pipe, at right angles, which latter pipe discharged into the public sewer in the roadway. The pipes in question were situate on private property. The result of the case was that the "common drain" was decided to be a "sewer," whilst the pipe connecting this common drain with the sewer remained a "single private drain" within the meaning of sect. 19 of the Act of 1890.

We have, therefore, under this ruling, two sewers (the public sewer and the "common drain") repairable by the local authority, connected by a "single private drain" repairable by private owners. The cases quoted may be taken as good examples of the many drainage cases which are continually coming before the Courts. In all instances in everyday work where any system of combined drainage is involved, special attention should be given to the legal aspect, so that, if possible, litigation may be prevented, and an equitable arrangement arrived at between all parties interested. It is hoped that the existing unsatisfactory state of drainage law will soon be amended.

The system of sewerage now generally adopted in England is the "combined system;" in this system the surface drainage and rain-water are carried off by the same channels as the sewage. Sometimes separate channels are provided to carry off the rainfall; this is called the "separate system," and involves two sets of channels; one to carry off the rain and storm waters, the washing of streets and open spaces; the other to carry off the sewage. The former discharge their contents into the nearest river or watercourse; the latter will convey the sewage to be treated in some one of the methods described subsequently. The advantages claimed for this are that smaller sewers are required, and that the amount of sewer-water is less, richer in quality and more regular in flow; no storm-waters enter the sewers to flood the lower districts of a town, and no road detritus is washed into the sewers. The disadvantages are that separate channels have to be provided, and rain-water washes away much that would pollute a stream; the scouring effect of rain on sewers is also lost, but this is a doubtful objection. Adoption of either plan must depend on local circumstances.

In every system of sewerage two objects are generally aimed at: first, sewage has to be removed, and this should be done by impervious pipes, such as glazed earthenware or iron, or brickwork laid in cement, very carefully laid and jointed; and secondly, when necessary, the subsoil must be drained. This may require

pervious drains or drain-sewers. If pipe-sewers only are used, the subsoil water remains unaffected, except so far as a small portion may find its way along the channels formed by the pipe. Sometimes pervious drains of earthenware are laid down to carry off the subsoil water. Brooks of Huddersfield has combined in one system a drain and sewer, in which there is an arrangement for subsoil drainage under the sewer-pipe. In this arrangement the subsoil drain and pipe-rest is first laid and clay-jointed; the cement-jointed pipe-sewer is laid afterwards on this, with the result of getting a better laid sewer, and at the same time effectually carrying off the subsoil water.

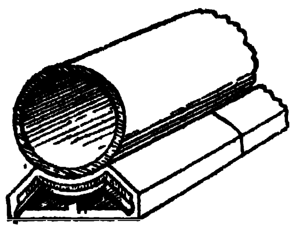


FIG. 58.—Brooks's combined sewer-drain and subsoil-pipe.

Sewers up to 18 inches diameter are generally made in earthenware and are circular in section. Cement and concrete are also used for pipes up to 18 inches, and are good and serviceable. Cast-iron pipes are also recommended: they are generally made up to 6 inches in diameter, and should be coated with Angus Smith's preservative to prevent erosion. If fluctuations in the amount of sewage are great, an egg-shaped sewer is preferable to the circular form; but if there is sufficient sewage to keep sewers constantly running, say half full, the circular section is best, being cheapest and strongest. If earthenware pipes are used, it is advisable to lay a foundation of concrete which supports the pipes in their length, and not at the sockets only. The joints must be cemented, and not puddled with clay, care being taken that the cement does not get inside the pipes, forming projections in the sewer against which solid matters will lodge and obstruct the flow of the sewage. Stanford's joint is composed of 1 part of boiled tar, 1 part of clean sand, and $1\frac{1}{2}$ parts of sulphur. This forms an excellent cement.

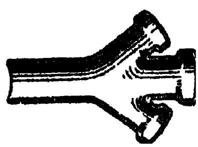


FIG. 59.—Junction pipe.

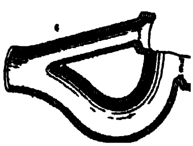


FIG. 60.—Trap with inspection pipe.

To avoid deposition of sediment, sewers should be laid in as straight lines as possible and with a regular fall; junctions should be made oblique, so that the sewage may enter in the direction of

the flow. The junction of drains is made by a special form of pipe, which may be either single or double (Fig. 59). If the sewer curves it should describe a wide sweep, the radius of the

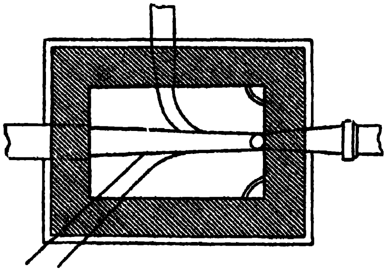


FIG. 61.—View of inspection chamber from above.

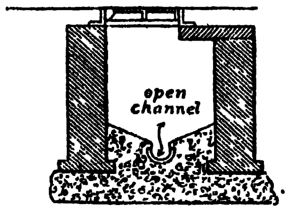


FIG. 62.—Sectional view of an inspection chamber.

curve not being less than ten times the cross-sectional diameter of the sewer. Inspection of pipes may be provided for by a manhole or by a disconnecting trap (Figs. 61 and 62).

Main sewers are generally made of well-cemented brickwork and egg-shaped in form, to give greater hydraulic depth, and, therefore, increased velocity with a small quantity of fluid. The egg-shaped sewer is formed by two circles touching one another; the diameter of the upper circle equals twice that of the lower, so that the invert is the narrowest part. This form of sewer secures the maximum scouring effect with the minimum quantity of water (Fig. 63).

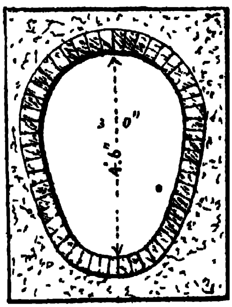


FIG. 63.—Oval sewer.

To secure a uniform flow, it is necessary to diminish friction as much as possible; and this is found to be least in this form of sewer, as the wetted perimeter is proportionately reduced, instead of being, as in every other form, relatively increased. The interior should be smoothly finished, and the sewer itself quite impervious and free from any inequality.

At each principal change of line or gradient there should be arrangements for inspecting flushing and ventilation; at all junctions and curves the fall should be increased to compensate for friction; the principal sewers should have special overflow pipes for any excess of rainfall; no junctions should be at right angles, nor opposite other junctions; tributary sewers should deliver in the direction of the main flow, and should have a fall into the main at least equal to the difference between their two

diameters; pipes of small size should always join on to pipes of larger size; if the tributary joins the main sewer below the level of the sewage in the latter, deposits are produced in the branch. Street gullies are generally provided to prevent the entry of gravel and solid matters into sewers. The debris collects in the gullies, while the water flows off by an opening to the sewer placed on a higher level, and the deposit is removed at intervals.

Fall of Sewers.—The amount of fall that should be given to sewers, or the inclination at which they should be laid, will depend upon the velocity of the current that it is desired to attain. To prevent deposit, in drains of 6 and 9 inches diameter the velocity should not be less than 3 feet per second; for 12 to 24-inch pipes, $2\frac{1}{2}$ feet; and for larger pipes, 2 feet per second.

The inclination or fall required is 1 inch in 40 for 4-inch drain, and 1 in 60 for a 6-inch drain, and for sewers from 1 in 244 to 1 in 784, according to size. Too much dip will cause the water to run away too forcibly, leaving the solid matter behind. If the fall is less, or if deposits occur, special means for cleansing are required. This is usually accomplished by manholes placed at intervals, the sewers running in straight lines from manhole to manhole. Where the current is feeble and deposits are liable to occur, automatic flush-tanks may be placed at the upper end of the sewer. Flushing is chiefly required in sewers with insufficient gradients, at "dead ends," and in hot dry seasons when the flow of sewage is smallest and decomposition most rapid. Field's automatic flush-tank may be used for this purpose; it acts by siphonage, so that the whole cistern empties itself with a sudden flush when the action is once started (Fig. 64).

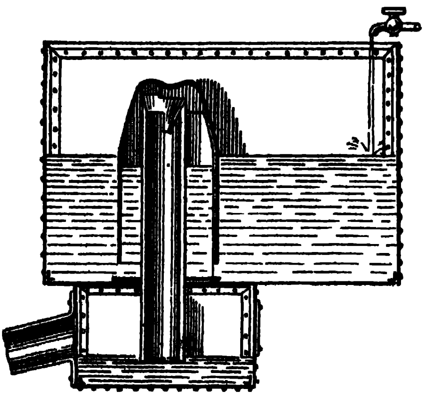


FIG. 64.—Field's flush-tank.

The action of the cistern is as follows: The base of the tube dips into the trapping-box, then, as the water rises in the cistern, it compresses the air in the tube. The water continues to rise in the dome of the siphon until it reaches the level of the lip, when on overflowing, the water falls down the centre of the tube, carrying with it a certain amount of air. This action continues until a partial vacuum is formed in the inner tube, and the siphonic

action due to the pressure of the atmosphere is commenced, when the whole contents of the cistern are discharged with great velocity. An important point to bear in mind is that, on fixing one of these cisterns, the dome of the siphon must be removed, and a few gallons of water poured into the lower chamber so as to form a trap.

The simplest formula for calculating velocity of flow through sewers or pipes is the following:—

$$V = 55 \times \sqrt{D \times 2F}$$

V = velocity in feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.
$V \times$ sectional area of current of fluid, in sq. feet, = discharge in cubic feet per minute $\times$ 6·23 = gallons per minute.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. Fall in fractional parts is converted into fall in feet per mile by dividing 5280 (number of feet in a mile) by the denominator of the fraction. Thus a fall of 1 foot per mile = 1 in 5280; 10 feet per mile, 1 in 528, and so on.

The hydraulic mean depth of a pipe of any shape equals the section area of the current of fluid divided by the wetted perimeter. The wetted perimeter is that part of the circumference of the pipe which is in contact with the fluid. The hydraulic mean depth in circular pipes is always one-fourth of the diameter.

Sewer Air.—In well-constructed sewers, where there is no deposit and the sewage is allowed to flow away without any obstacle to the outlets, the air is much better than might be expected. In Carnelley and Haldane's experiments in the main sewer of Westminster and in various sewers in Dundee, the carbon dioxide was about twice, and the organic matter, estimated by the permanganate process, about three times as great as in the outside air at the same time; while the number of micro-organisms was less in sewer air than in the outside air, and in smaller number than in the air in any class of house they had investigated. The excess of the carbon dioxide was probably due to the oxidation of the organic matter in the sewage and in the sewer air, and, in part, to the diffusion into the sewer of air from the neighbouring soil. The few micro-organisms present, compared with the external air, is explained by the tendency these have to be deposited on the damp surfaces of the sewers; with ordinary air-currents they are not disturbed or given off to the surrounding atmosphere; those present nearly all came from

the outside air, and their number is directly proportional to the number present in the external air at the time. These experiments agree with those made by Parry-Laws, and Andrewes, for the London County Council. They found, as the result of their observations on sewer air, that the micro-organisms in sewer air are related to those in the outside air and not to the micro-organisms in sewage, and, *in the absence of splashing*, there is very little ground for supposing that the micro-organisms in sewage become disseminated in the sewer air. In badly constructed sewers, or where deposits take place which undergo putrefaction, such favourable results are not found, and disease has been traced to the entry of infected sewer gas into houses through untrapped drains and openings into them. Pettenkofer has pointed out the distinction between *sewer air*, which is generally without smell and harmless, and *sewer gas*, which is always the result of stagnation, deposit, and putrefaction, and recent experiments show the necessity of making this distinction.

Ventilation of Sewers.—Sewers cannot be constructed air-tight on account of the very numerous openings into them; the tension of the air is generally not very different from that of the atmosphere outside, while the movement of the air is usually in the direction of the flow of the current. Certain conditions, however, are present which produce movement of air in sewers, the chief being—the variation in temperature in the sewer and in the external air; barometric pressure; the passage of hot water from houses or manufactories, causing a rise of temperature in the sewage and consequent expansion of the air in the sewer; the blowing off of steam, which increases the temperature and pressure suddenly; and the sudden increase of water flowing into the sewers. Any of these conditions may expel air from the sewer or draw air in from the external atmosphere. Tidal water in sewers is not so liable to cause violent movements of the air in them, as the rise of the tide is gradual.

The simplest plan for ventilating sewers is by means of a shaft from the crown of the sewer to the surface of the street or road above, where it is covered by an iron grid. The mud and gravel which may fall through the grid is caught in a tray placed beneath the grating, but which allows the free passage of air around it. One such opening is placed commonly at intervals of a hundred yards or so. This system has been subjected to much criticism, mainly on account of the fact that it favours the discharge of objectionable gases from sewers more or less immediately under the noses of passers-by. As a routine practice, this plan of open ventilating grids at road level is to be discouraged. If sewers need ventilating, a preferable method is to

locate along their course at suitable intervals tall iron shafts, provided with rust pockets, and carried sufficiently high as to permit of the escape of air and gases at a level well above the roofs of houses. As a matter of fact, however, if sewers are well constructed, have sufficient fall and flush of water, obviating the local accumulation of decomposing material, there should be no accumulation of foul gases. These ideal conditions, however, are not always existent; in which cases the only way to cope with the nuisance from sewer emanations is by abolishing dead ends of sewers or ventilating them, by erecting pipe ventilators in substitution of offensive gratings at street level, by the pan siphon trapping of offensive street gullies and the free admission or circulation of air in the sewers. The latter detail will do good by favouring oxidation of any putrescent matter and by diluting any offensive gases evolved. Recently, an agitation has been started to solve this question of sewer ventilation, by advocating the abolition of the intercepting trap on the house-drain between the sewer and the house, thereby converting every house-drain and the soil-pipes discharging thereto into so many sewer ventilators. The main objection to this proposal is that it would destroy the drain isolation, which is now possible, of each house from the rest of the houses of a district. Moreover, as we cannot rely absolutely upon the soundness of every sanitary fitting in individual houses, the risks of sewer gas gaining direct access into dwellings would be considerable. It is true the intercepting trap is not an ideal sanitary appliance, but we have to choose between two evils, namely, having sewer gas laid on to the house, or having the efficiency of the house-drain somewhat interfered with; and the latter is the lesser evil.

Pneumatic Methods of removing Sewage.—These are practically three in number, namely, the Liernur, the Berlier, and the Shone systems. That proposed by Liernur has been carried out on the Continent, in places where, owing to the situation, any fall for sewerage is not possible. There are two separate sets of drains; the one, a pipe of small diameter, being used for waste-water from houses and factories; the other, of cast-iron pipes, 5 inches in diameter, is connected with the closets, and carries away the excreta from closets and bedroom slops. It is intended that the contents of the former should be allowed to flow at once into any river or stream, as it is only slightly polluted, solid matters having been first separated by strainers, or, if necessary, by filtration. The sewage proper is conveyed by pipes to small reservoirs or tanks placed at intervals along the street; these are made to connect with larger tanks, which, again, communicate with a central reservoir at the sewage works. A vacuum, being produced

by an engine working an air-pump at the central works, extends through the whole series of pipes; these are fitted with stop-cocks, and the contents of the tanks and street reservoirs are discharged into the central one, from which it is pumped out and manufactured into poudrette. The extracting force is said to equal a pressure of 1500 lbs. per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. This system has the disadvantage of not disposing of waste and slop-waters, for the removal of which sewers are required. There is also the possibility of the pipes being clogged with fæcal matter, and it is impossible to disconnect the house-pipe from the reservoir by an efficient trap. The system is a complicated one and does not do its work automatically, nor are excreta removed from houses immediately. A successful installation has been working at Stanstead in Essex, and for low-lying districts, where suitable sewer gradients are difficult to secure, this system offers considerable prospects of success.

The Berlier system is very similar in principle to that of Liernur. The soil-pipe, which is generally 6 or 8 inches in diameter, and of cast iron, opens at the lower end into an iron vessel called a *receiver*, within which is an ironwork circular basket, with the iron wires far apart, in which all hard substances and foreign bodies are retained. Whatever leaves the basket is in a fit condition to travel along the pipes without giving rise to any danger of obstruction. From the bottom of the receiver, the sewage passes into the *evacuator*, to which an exhaust is attached at the bottom. When the receiver is full, the valve opens, and the contents are drawn into the exhaust pipe. This system works automatically, which is an improvement on the Liernur plan.

The Shone system acts by means of compressed air, and is usually worked from a central steam-engine. This plan is not applied to water-closets, but is a device for raising sewage from one level to another when the ground is flat and a proper fall cannot be secured. The sewage is received into "ejectors," which are cylindrical reservoirs placed beneath the level of the ground and, after a certain quantity has entered, act by means of a float on a counterpoised lever opening a valve and admitting the compressed air, which forcibly ejects the sewage into the further length of sewer-pipe, or to an outfall direct. The compressed-air tubes are conducted along the upper flat outer surface of the reservoir; the arrangement is carried out by valves acting automatically, which permit of the escape of the expanded air as well as the admission of the compressed air. This plan is especially useful where the ground is flat, and where it is difficult to get a fall.

Disposal of Sewage.—This is still one of the most difficult problems of the day. Although the question of the disposal of sewage is distinct from that of its removal, yet the method of disposal is dependent, to some extent, upon the method of removal. In the dry method of removal the final disposal of the fæcal matter is mainly as a fertilizer or manure upon cultivated land. If the removal is by water, the ultimate disposal of the sewage may be without any attempt at purification as by discharge into the sea, running water, or into a cesspool; or it may be subjected to various methods of purification, such as separation of the solid and liquid parts either by subsidence or precipitation by chemicals, filtration through land, or various artificial media, and bacterial methods.

Discharge into the Sea.—When sewers discharge into the sea, the outlet should always be under water; care must be taken to carry the sewage well out to sea, so that it may not return with the tide and be deposited on the fore-shore. Tidal currents should be taken advantage of to prevent this; there should be a tide flap opening outwards, to prevent ingress of tide and wind blowing up the sewer; the tide will block sewage at certain times, and this, in the case of low-lying towns, necessitates a "tank sewer," to store the sewage that flows down during this period; but with this method, decomposition and evolution of gas and ammonia compounds are very liable to take place; it requires special attention.

Discharge into Rivers, etc.—This is prohibited by the Rivers Pollution Acts of 1876 and 1890. It is illegal to pollute any stream or river by allowing crude sewage to flow into it.

The Cesspool System.—This system must be regarded only as temporary and partial; it provides for the immediate removal from the house of the excreta and foul waters, but only to a short distance, where it is received into a cesspool, which has to be emptied from time to time. Cesspools are generally constructed of brick, and in the majority of cases the solid matters only are retained, the liquids passing into the surrounding subsoil and infiltrating it for some distance around. In some cases the cesspool is lined with cement, so as to be more or less impervious, and in this case an overflow-pipe must always be provided.

The cesspool or dead-well is really the only method available in a country place. In this system the tank can never be quite water-tight, therefore the surrounding soil gets polluted, and the water-supply must not be derived from anywhere near; the amount of percolation depends largely on the nature of the soil.

Cesspools should be placed at least 50 feet distant from any dwelling, and 100 feet from any well, spring, or stream. They

should always be at a lower level than the well from which the drinking water is taken, and to leeward of it, so as not to pollute the saturated portion of the permeable stratum above the well. They should be ventilated and emptied at regular intervals; it is often found convenient to utilize the liquid contents, by distributing this over the gardens or adjoining fields, and for this purpose a small hand-pump is usually attached, connected with a distributing-pipe or channel. Complete disconnection by proper traps and efficient ventilation are necessary to make this a sanitary method.

Purification of Sewage.—This presents great difficulties, and many methods have been suggested and tried with varying success. For the complete purification of sewage, three processes are involved: first, clarification; secondly, an alteration of the chemical constitution of the organic putrescible matter in solution in sewage, whereby it will not undergo any further putrefactive changes; thirdly, the removal of disease-producing bacteria. These results are not obtained equally by the various methods which have been suggested. The more important are the following: chemical treatment, land treatment, and biological methods.

Chemical Treatment.—The processes suggested for the purification of sewage under this head are mainly precipitation methods. One of the principal substances used for precipitating or clarifying sewage is lime. The quantity used depends on the character of the sewage, and varies from 6 to 12 grs. or more of quicklime for each gallon of sewage. If the effluent is made alkaline by the addition of too much lime it undergoes putrefaction rapidly; it has been attempted to prevent this by adding chloride of iron to the quicklime, by which means purification is delayed but not prevented; the process is simple and cheap, but as the organic matters in suspension only are acted on, it has failed to produce either a valuable manure or the purification of the offensive liquid. Precipitation has little effect on the removal of microbes, pathogenic or otherwise.

Among other processes which have been tried in different places may be mentioned those which employ lime and alum, lime and sulphate of iron, also the Amines process, and the ferrozone and polarite filtration method. In London a chemical process has been applied to the sewage before its discharge into the sea. This consists in adding 3·7 grs. of lime and 2·5 grs. of sulphate of iron to every gallon of sewage; it produces an average reduction of 18 per cent. of dissolved oxidizable organic matter.

The Amines process consists in mixing herring brine (3 grs.) with lime (30 to 50 grs. per gallon), and passing the volatile matters so produced, composed of amines and ammonia, into

crude sewage, which, it is said, is completely sterilized by this means. The clarification is very rapid and complete, and a heavy, nearly inodorous sludge, which does not become putrescent, is produced.

In some places, polarite or magnetic spongy carbon has been used as a filter for sewage, the solid and some of the dissolved material being first precipitated by ferrozone or magnetic ferrous carbon.

All these precipitation or so-called chemical processes do, to a certain extent, purify sewage, chiefly by removal of suspended matters; but they leave a large amount of putrescible matter in the effluent, and produce considerable quantities of precipitated material, known as sludge. This sludge possesses very little manurial value, and is composed chiefly of the organic and mineral matters precipitated from the sewage, and usually contains about 90 per cent. of water. When pressed in a filter the amount of water is reduced to between 40 and 50 per cent.; these cakes are subsequently ground into powder and used as manure. The liquid expressed is very impure, and has to be subsequently treated in the same way as the original sewage. It is an exceedingly strong and odorous liquid. The composition of the pressed sewage sludge at Crossness is stated to be—water, 58 per cent.; organic matter, 17 per cent.; mineral matter, 25 per cent.

The effluents produced are fairly satisfactory; there is very little suspended matters, and a very large proportion of the organic constituents are precipitated and retained in the sludge. If passed into a river or stream in which the volume of water is large, they are readily disposed of without creating a nuisance or silting up the bed of the river. In some cases it has been found necessary to filter the effluent through coke filters before discharging it into a stream. The effluent has not much manurial value.

Webster proposed to purify sewage by electrolysis. The chemical change that takes place in sewage when it is electrolyzed depends chiefly on the fact that water as well as the chlorides of sodium and magnesium are split up by the electric current into their constituent parts, chlorine and oxygen being set free at the positive pole, and uniting to form hypochlorous acid; this being intensely active, and liberated in a nascent state, oxidizes the organic matter in the sewage into innocuous compounds, as well as attacking the iron plates, forming hypochlorite of iron; at the negative pole, potash, soda, magnesia, ammonia, etc., are set free. Cast-iron plates are used as electrodes, and give the best results. The effluent produced by this process contains about 3 grs. per gallon of suspended matters, which consist almost entirely of oxide of iron. It is subsequently filtered through filtering beds of sand

and coke, and passed on to land, if this is convenient, as it has a certain manurial value. The sludge is dug into waste land or shipped out to sea.

The treatment of sewage with electrolyzed sea-water was the basis of the Hermite process, and has lately been revived in what is known as the oxy-chloride method. In this latter procedure, ordinary salt water replaces sea-water. The result is a liquid disinfectant, containing hypochlorites, which is almost odourless and inoffensive. It is claimed for both these processes that sewage, when mixed with these liquids, is rendered practically inert and sterile. We have no experience of the oxy-chloride, but we know that Hermite water is very destructive to all taps and metal fittings. Neither process is suited for general use in buildings, but rather for flushing defective sewers, or deodorizing and sterilizing clarified sewage.

Land Treatment.—The utilization of land as a medium for the purification and disposal of sewage has been accomplished in various ways. The sewage is passed on to the land either in its crude state or after some preliminary course of straining, or after clarification and precipitation of its grosser suspended matter by some form of chemical treatment. The application of sewage to land is conducted usually on one or other of two methods, namely, irrigation or intermittent downward filtration. If the sewage is discharged on to a piece of land, having in view a maximum growth of vegetation for the amount of sewage supplied, it is known as irrigation; if it is discharged upon land specially prepared to receive it, making the crops or product therefrom of secondary importance, it is known as filtration.

In *irrigation* schemes, the soil must have a gentle slope and be drained by subsoil drains placed about 5 or 6 feet deep, by which the effluent can be conveyed to the nearest watercourse. To ensure success, the area must be sufficient and the sewage passed on at intervals, so as to permit of aeration of the soil. The land is laid out in ridges and furrows, and the sewage made to reach it in as fresh a state as possible, also freed from its coarser material by settlement or precipitation. Although sewage farms of this nature are not a commercial success, still immense crops of coarse grass can be obtained from them. Under favourable conditions, the purification of the sewage is excellent, the chief disturbing factors being frost and excessive rainfall. For dealing with sewage by this method, a large quantity of land is required—about 1 acre for the sewage of 100 persons.

Land *filtration* of sewage may be upward or downward; the former is now practically abandoned as being totally inefficient. The process of filtration is essentially one of oxidation and

nitrification, while intermittency of application is a *sine quâ non*, even in suitable soils; hence the process is commonly spoken of as intermittent downward filtration. The action of the land is also mechanical. As regards the soil itself, the physical conditions, porosity and fineness of division, have more to do with its cleansing power than its chemical composition. The best soil seems to be a loose marl, containing hydrated iron oxide and alumina.

The conditions necessary for the successful filtration of sewage through land are: (1) a porous soil; (2) an effluent drain not less than 6 feet from the surface; (3) proper fall of land to allow the sewage to spread over the whole land; and (4) division of filtering area into four parts, each part to receive the sewage for six hours, and to have an interval of eighteen hours. The quantity of land required is about 1 acre to purify the sewage of 1000 persons, and the larger solid bodies should be removed by straining before allowing the sewage to flow on to the land. When the amount of available land is limited, the sewage may be first treated by precipitation before allowing it to flow on the land, but this will deprive it of much of its manurial value. If the sewage be previously treated, 1 acre of land will suffice to receive the sewage of from 2000 to 5000 persons.

The effluent is excellent after filtration, if the details of the process have been carefully carried out, and is quite fit to be discharged into any river or stream. The solids form a fine cake on the surface, and can readily be broken up and mixed with the soil. Generally all crops grow well on these sewage farms, but Italian rye grass and green vegetables do best. In Paris all kinds of vegetables and fruit trees are grown, and appear to thrive excellently under this treatment. When properly carried out, this is a valuable method for the purification and utilization of sewage, but it will be readily understood that, in view of the difficulty experienced in obtaining a sufficient area of suitable land, there are distinct limitations to its practicability.

Biological Methods.—Strictly speaking, the passage of sewage on to and through land is a biological method of treatment, inasmuch as it aims at, and more or less secures, a destruction of sewage as sewage, and a building up of new substances in its place by means of the organisms normally present in the sewage or in the land through which it is made to filter. Until recent years, land filtration was the only biological method of treating sewage available or practised. The difficulties associated with the securing of sufficient suitable land led to a closer study of the problem, and the development of new applications of the biological treatment of sewage has been a striking feature of recent sanitary effort. These new departures depend essentially upon bacteria contained in the

sewage itself, and are based on the principle that organic changes in sewage are mainly due to bacterial action, and aim at fostering and assisting these changes by placing the sewage under the most favourable conditions for undergoing disintegration and oxidation by means of micro-organic life. Practically they are the direct antithesis of all methods of treating sewage by chemicals which, being for the most part antiseptic in action, modify and largely neutralize the vital action of the bacteria present in sewage. The micro-organisms existing normally in sewage may be said to consist broadly of two classes, namely, the "anaerobes" or those which exist without oxygen, and the "aerobes" or those to whom oxygen is essential. To those of the first group falls the main share of the work of breaking down, digesting, and liquefying the solid organic matter of sewage, whereby it is reduced to simple chemical states, chiefly ammonia; while on those of the second group devolves the duty and work of oxidizing, mineralizing, or nitrifying the ammoniacal substances into nitrites and nitrates.

The actual changes which take place in sewage, as the result of bacterial action, are somewhat complex and obscure, but they have been aptly described by Rideal as consisting mainly of three stages. In the first stage, or that of anaerobic liquefaction and preparation by hydrolysis, the albuminous matters, cellulose, and fats are broken up into soluble nitrogenous compounds, fatty acids, phenol derivatives, gases, and ammonia. In the second stage, or that of semi-anaerobic disintegration of the intermediate dissolved bodies, a further formation of ammonia, nitrites, and gases takes place. In the third stage, or that of aeration and nitrification, ammonia and carbon residues are changed into water, carbon dioxide, and nitrates.

A large variety of installations have been devised to secure these really natural or biological changes in sewage; though they differ from each other in matters of detail, they all are the same in principle. As representing the best and most typical, we may consider those suggested by Scott-Moncrieff, Cameron, and Stoddart.

The Scott-Moncrieff installation consists of a liquefying or digesting chamber, filled with large stones and open at the top. The sewage, entering at the bottom, through a restricting chamber, passes upwards and onwards continuously, but sufficiently slowly to be acted upon by the anaerobic and liquefying organisms, which form dense colonies in the nidus formed by the stones, and which, under the favourable conditions presented to them, increase in proportion to the work required of them. The result is, that the solid organic matter is liquefied, and an effluent, which is practically without solids in suspension, passes on. This is the first stage.

The second stage is conceived with a view to place the liquid sewage under such favourable conditions that the nitrifying and aerobic organisms would multiply similarly to the organisms of liquefaction, and complete the process by nitrification.

The arrangement adopted consists of a series of trays containing filtering media (stones or coke) placed one above the other, and with intervening air-spaces a few inches between them. The series are in duplicate, and the sewage is delivered over the surface of the upper trays alternately, by means of a dipping trough. The liquid passes slowly downwards through the various trays in the form of a slow but heavy dropping rain, meeting, under the most favourable conditions of aeration, the organisms of nitrification, and finally passes away to a stream or on to land

We have had opportunities of examining a number of effluents from one of these installations, and found them to be remarkably clear, free from smell, wonderfully stable, and exhibiting very high degrees of nitrification and purification.

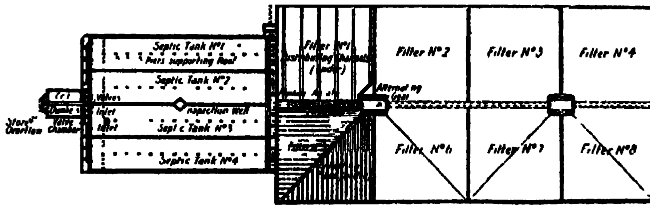


FIG. 65 —Plan of a septic tank with contact beds installation.

The installation first suggested by Cameron of Exeter is sometimes called the septic tank system. In it the sewage is first led into a tank from which air and light are excluded. Digestive changes take place in the sewage within this tank as the result of anaerobic bacterial action, which is favoured by the darkness, the absence of air, and the perfect stillness at which the sewage is maintained. Under these influences much of the solid matter is rendered soluble and dissolved. After remaining twenty-four hours in the tank, the sewage is drawn off without disturbing its surface, and passes away in a thin stream along an open trough or aerator, over the edge of which it flows into automatic tippers, which ultimately discharge it on to filter-beds. At this stage the sewage appears as merely dirty water having comparatively little offensive smell, and, running along and over the trough, becomes largely aerated by exposure to the air.

The filter-beds consist of clinkers and coke breeze, in which the aerobic and nitrifying organisms attack the sewage constituents and complete the work of organic disintegration commenced in

the septic tank. The filters are filled, and the sewage distributed on to them by an automatic gear. Each filter-bed takes six hours to fill, remains full for six hours, is emptied in half an hour, and aerates for eleven and a half hours.

Filtrates or effluents from the Exeter installation which have come under our notice have been bright, clear, and stable. In this process the action of the anaerobic organisms is encouraged by the special construction of the tank, and carefully differentiated, as in Scott-Moncrieff's method, from the subsequent aerobic action due to other organisms, in the filters. The periodical resting and aerating of the filter-beds obviously helps to maintain the activity of the aerobic bacteria.

Modifications of the septic tank system have been successfully worked at Manchester and elsewhere, using an open septic tank and double filtration through bacterial filter-beds, or, as they are often called, first and second contact-beds.

It is clear that in these ordinary filter or bacteria beds as mentioned above, and which are intermittently flooded with sewage and then allowed to aerate, the different reactions or activities of bacterial species are somewhat fortuitously confused and reversed according to the periods of filling or rest. The objections to this condition suggested the employment of continuous filtration of sewage through a coke or breeze bed.

A continuous bacterial filter of the simplest description is that of Stoddart, and which has given excellent results at Horfield. This filter is not intended to deal with crude sewage, but only with sewage which has been treated previously, either by precipitation or by anaerobic bacterial action. The filter consists merely of a mass of coarse rubble, clinker, ballast, coke, or other material placed upon a concrete floor, laid with sufficient fall to cause any liquid that reaches it to flow towards the nearest external surface. The absence of impermeable retaining walls favour the free aeration of the filter: its depth may be anything from 1 to 12 feet. The essence of Stoddart's method is continuous filtration through the bed, and not intermittent filtration as in Cameron's installation. In order to maintain the continuous filtration with the maximum of efficiency, it is considered essential that the sewage should be applied over the whole upper surface of the filter in fine streams of drops at such a rate that the maximum amount shall be passed without charging any part of the filter with visible liquid. This even distribution of the sewage over the filter is secured by patent "distributors," each distributor consisting of corrugated iron, presenting alternate ridges and gutters. The ridges are notched by V-shaped openings at regular intervals. A series of vertical points is provided beneath the lower surface of each gutter by

driving nails through the bottom. The chief advantages claimed for this continuous filtration are, the extreme simplicity of construction and management, the relatively small area of bed required, and the extraordinary rapidity with which sewage may be passed through the filter with the production of a satisfactory effluent.

It must not be supposed that these three systems exhaust the list of biological methods which have been suggested for treating sewage, they merely represent three types of installation. There are many others which have met with varying degrees of success, but all are based upon the principles which have been explained, involving some form of preliminary treatment of the sewage by solution of the suspended solids in either a digestive or detritus tank, and followed by aeration and oxidation by passage through one or more contact or filter-beds. In connection with these various kinds of biological installation, there are some points of practical moment which need noting. At the outset it is necessary to realize that these sewage filters differ essentially from water filters, in that the latter act as interceptors of micro-organism, while the former act as a meshwork of bacteria preying actively upon the sewage. While the average depth of a bacteria or filter-bed is about 4 feet, it must not be supposed that this is a hard-and-fast rule: they may be 12 feet deep, and will work efficiently, so long as they are filled rapidly and aerated systematically. The filtering material is of the greatest importance, and upon its choice the success or failure of a particular installation often depends. Probably the most all-round useful material is clinker, the lower layer being $\frac{3}{4}$ inch and the upper layer 3 inches in size. For secondary contact beds, the size of the clinker need not exceed from $\frac{1}{4}$ to $\frac{1}{2}$ inch. If clinker from refuse destructors cannot be procured, breeze from gas-retorts is often used, and failing either of these materials, burnt brick or hard broken stones make an efficient matrix. If the filtering material readily crumbles or disintegrates, it leads to rapid clogging of the bed and much loss of capacity. All contact-beds suffer a rapid initial decrease of capacity, but afterwards, with careful working, the rate of decrease is much less. A filter-bed should be worked very slowly at first, in order to allow it to settle down and the essential bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed while the material is still loose and open. Good results cannot be expected from new installations, as the beds must get ripe; the work thrown on to a recent filter should not be increased till analysis reveals the presence of surplus oxygen, either dissolved or in the form of nitrates in the effluent. All variations in

capacity should be recorded, and if the capacity decreases rapidly, a period of rest should be allowed. In cold weather, long periods of rest appear to be a mistake; it is better to lessen the work of the filter by reducing the number of fillings rather than give a long rest at one time. Where septic tanks are in use, a not infrequent source of trouble is the steady loss in their capacity due to continuous extension downwards of the scum which forms on the surface: it is not quite clear to what cause this is due, but the only remedy seems to be a periodical removal of the upper layers by careful scraping or skimming. It need hardly, perhaps, be remarked that the access of antiseptics or disinfectants, in large quantities, to sewage intended for biological treatment should be avoided, otherwise the process will be seriously interfered with.

Comparison of the Different Methods.—Considering all the conditions involved, it appears impossible for all places to adopt the same plan, and the local circumstances of each place must be taken into account in determining the best method for the removal and disposal of excreta. The principle to be aimed at is the immediate and complete removal of all kinds of refuse from the vicinity of habitations in the most expeditious manner.

There can be no doubt about the main principle of sewage disposal, that animal waste products should be as quickly as possible submitted to the action of growing plants, and thus converted from dangerous impurities into wholesome food. The difficulty lies in its application.

The dry methods do not answer this requirement, as the excreta is only removed at intervals, and although deodorization may be complete, disinfection is not attempted. For a large population, therefore, some system of water-carriage is necessary.

Having, therefore, sewage to deal with, we must get rid of it in the least objectionable manner. It must not be sent into rivers; therefore, where land is available, immediate application to the land either by intermittent downward filtration or irrigation is indicated.

By intermittent downward filtration sewage can be purified, so that the effluent water may be permitted to run into any stream or river, the water of which is not required for drinking purposes. Little, however, of the manurial value is saved, the greater part passing away in the effluent. Irrigation accomplishes all that is done by intermittent downward filtration, with the further advantage that the whole of the manurial constituents of the sewage are returned to the soil, which is fertilized by them. Both systems are, however, often impracticable owing to lack of suitable land.

As regards the biological treatment of sewage, it can now be definitely stated that the average results are as good as those given by well-managed sewage farms, whilst the best results are a long way better than those recorded of any sewage farm. A most important feature in the biological treatment of sewage as compared with any chemical process is that, when properly carried out, it yields an effluent which is incapable of secondary putrefaction. In this respect it may be regarded as the best solution of the sewage problem, because the stability of an effluent which has been mineralized by a biological process is absolutely secure. We feel convinced that biological methods of treating sewage are not only scientifically correct, but sufficiently efficient and economical in their working as to quite preclude any reversion to artificial methods, such as treatment by chemicals or electricity.

Another important point in connection with the biological process is that, by the adoption of it, sludge may be looked upon as a practically negligible quantity. In connection with nearly all sewage-disposal processes hitherto adopted on a large scale, the by-product of sludge has given great trouble, not only on account of the necessity of dealing with it at the works, but because of its great bulk and the difficulty of disposing of it. By the biological process, however, practically all sludge may be avoided.

There is, of course, a certain amount of grit and other mineral matter mixed up with the sewage, but this must be eliminated by what are called grit chambers, provided in front of an installation.

Though bacterial or biological systems are important advances in the treatment of sewage, especially in destroying and rendering the organic matter soluble, the resulting effluents are teeming with microbial life—in fact, in this sense, are little different from the original sewage. Moreover, we know that specific and pathogenic bacteria do survive passage through these installations, and can find their way into the resulting effluents. Houston's observations on this point, made for the Royal Commission on Sewage Disposal, are of interest and importance. In these experiments *B. pyocyaneus* was added deliberately to sewage, both at Hendon and at Leeds: at the former place as the sewage flowed on to a continuous filter of the Ducat type, and at the latter place as it flowed into a septic tank preliminary to contact-beds. In the case of the continuous filter-bed, *B. pyocyaneus* appeared in the effluents within *less than ten minutes* from the start of the experiment, and was present, at first invariably, later at irregular intervals, up to the tenth day. In the case of the septic tank and contact-bed, *B. pyocyaneus* appeared in the septic-tank liquor *within two and a half hours* from the start of the experiment, and

in the contact-bed effluents at the earliest possible times—that is, the first emptying of the bed. The organism was recovered from both the septic-tank liquor and from the contact-bed effluent as late as the ninth day.

These are very striking results, and suggestive that effluents from biological installations are by no means free from danger if discharged direct into running streams. For this reason it is usual to pass all effluents from biological sewage installations either on to land or through a special sand filter before allowing them to gain access to a stream. Provided such stream is of reasonable volume, and taking into consideration the remarkable natural purification of water which occurs as the result of the action of light, movement, and sedimentation in a flowing river, we question whether this precaution of always passing sewage effluents after biological treatment on to land is altogether necessary. We cannot hope to obtain a sterile effluent, and there is no evidence to show that even after passage through land the final effluent is free from objectionable micro-organisms. We think sufficient safeguards exist for the public health if the water authority filters its water when drawn from rivers, irrespective of whether it received an effluent or not higher up.

As to individual systems we cannot dogmatize; a type of installation which yields excellent results in one place may not do so necessarily in another. The requirement of each and every place must be determined by local circumstances, and no hard-and-fast rules can be laid down as to whether a system of contact-beds or a continuous filter installation is the better.

Doubtless, in the near future, further developments in the biological treatment of sewage will occur. These probably will assume the form of a greater and more exact control, not only of anaerobic, but also of aerobic action. In other words, we shall be able to establish standards for treating sewage in anaerobic beds or tanks for a definite time, and subsequently treating it in aerobic beds containing particles of definite size, and the flow of both sewage and air being so controlled and regulated as to pass through the installation in definite quantities. A notable advance in this direction is the standardization apparatus suggested by Scott-Moncrieff for determining the essential factors for success in the purification of sewage by passage through filter-beds. Before attempting to design bacterial installations, the values of the following factors should be known for any particular sewage: (*a*) the volume to be discharged upon each foot of filter bed per hour, or each acre for twenty-four hours; (*b*) the period of time between each discharge; (*c*) the air required for aeration per cubic foot or yard of filter; (*d*) depth and nature of filter required

for any given standard of purification. The apparatus consists of an air-tight box of standard dimensions occupying a floor-space of 4 feet by 3 feet, and some 8 feet in height. It contains a unit of filtering material representing the actual working of a filter-bed, 6 feet in depth. By an automatic tipper, provision is made to determine accurately the volume and rate of delivery of sewage. also, by means of a metre, of the amount of air necessary to secure any standard of nitrification. By means of taps, samples of effluent can be taken at every foot-level from 1 to 6. A series of observations made with this standardizer enables one to determine accurately the character of an effluent obtainable from a given sewage under given conditions. We confess to being much impressed with not only the scientific value of this apparatus, but also with its practical importance to all called upon to either advise as to, or actually construct, bacterial sewage installations. It is doubtful whether either the engineering or medical professions fully realize the value and importance of systematic work with this apparatus. The essential data for filter-beds and contact-beds are only to be obtained by either employing some such standardizer, or by setting up a complete installation and gaining experience and knowledge of the facts by costly practical treatment of the sewage in bulk. The one method is logical, scientific, and in most cases likely to be the more economical; the other is purely empirical, and not infrequently as costly as it is unsatisfactory.

CHAPTER VI.

PERSONAL HYGIENE.

By the term Personal Hygiene is meant the consideration of those matters which concern the person's own health, and which relate only to the individual himself or herself. It includes the discussion of such subjects as Habits, Washing and Bathing, Clothing, and Exercise.

Habits.

Our habits may be either important aids to the promotion of health and the lengthening of life, or they may be important predisposing causes of disease.

Eating and Drinking.—It is of the greatest importance that all young people be taught to chew their food carefully and to eat slowly, as quick eaters generally suffer from indigestion later on in life. The excessive use of condiments and spices is a habit not to be encouraged. In youth we may eat plentifully, but in old age we should eat sparingly. The evils of intemperate habits and excess in alcoholic drinks are incalculable. Alcohol, besides rendering man's capabilities for work less, deadens the activity of the mind, interferes with the oxidation of waste matters in the blood, and so alters the character and function of the internal organs, particularly the liver and kidneys, that disease and death therefrom are, in most cases, the early result for those who habitually take alcohol in excess.

Smoking is another doubtful habit, and one for which there is not the slightest reason or excuse under twenty-one years of age. For elderly persons, or those in middle life, particularly when engaged in much mental or other work, the use of tobacco often soothes the mind and otherwise acts sufficiently as a restorative to the exhausted or fatigued nervous system as to justify the continuance of the practice.

Sleep.—The habit of taking sleep regularly is essential to health, for both body and mind need periodical rest, and it is only during sleep that this is obtained. Children need more sleep than grown-up people ; small children should sleep at least twelve hours a day, young lads and girls about nine hours, and adults about seven hours in a day. Night is the natural time for sleep. If possible, all people should sleep upon beds and bedsteads ; to sleep upon the floor and ground is frequently unhealthy, as it interferes with the free circulation of air under and around the sleeper, and, moreover, favours the inhalation from the floors and ground of gases and vapours, which are best avoided if possible. Plenty of fresh air is wanted at night and during sleep ; hence people should not sleep with the head covered up, neither should they lie in draughts and cold currents of air ; the body needs to be kept warm at night to avoid chills. All bedding should be kept clean and fresh, as waste matters from the body stick to them and, if allowed to remain dirty, give rise to ill health.

The regular removal of waste substances from the body is most necessary for the preservation of health ; for if they are not removed, they become re-absorbed into the blood, and there act as poisons. Since the organs by which waste matters are removed from the body are the lungs, the skin, the kidneys, and intestines, it is important that all should early acquire habits suitable for keeping them in proper action. The chief agents in regulating the action of the first three are cleanliness and exercise ; with

regard to the last, the formation of a regular habit early in life is essential, while exercise also helps the action of the intestinal canal.

Another good and important habit is that of cleansing the teeth; this should be done at least twice a day; such a practice, besides keeping the mouth clean and sweet, helps to preserve the teeth themselves, and prevent their decay. For those teeth which are decayed, much can be done by going to the dentist, and having the decayed parts cleaned out and "stopped," or plugged, so as to avoid any further extension of the decaying process.

Washing and Bathing.

If the skin is not kept thoroughly clean, the dead scales of it, which ought to be removed, collect upon the surface and, with dirt, block up and check the proper action of the many glands contained in the skin. If the skin does not do its work properly, more has to be done by the lungs and kidneys; and these, if they have too much to do, are likely to get diseased from overwork. The free use of water is an excellent stimulant and tonic to the skin; but to remove dirt and grease and for purposes of cleanliness, bathing or washing without the use of soap and friction is useless.

Soap is either a potassium or sodium salt of one of the fatty acids, stearic, oleic, palmitic acid, etc., produced by the action of either potash or soda upon the fats. As the result of this action of these alkalis upon the fat acids, not only is an alkaline salt of the fat acid formed—that is, a soap—but also glycerine is set free. Potash soaps are very deliquescent, retaining so much water as to form often a soft jelly; of this kind is *soft soap.* Soda soap retains little water, and readily hardens when exposed to the air, constituting hard soap. Ordinary soft soap is largely made from whale or seal oil, and the drying vegetable oils, such as linseed oil. Ordinary hard soaps are commonly made from tallow and the non-drying vegetable fats and oils, their hardness being in proportion to the stearic and palmitic acid which they contain. *Marine soap*, or soap used for washing in sea-water, is made by the action of potash or soda upon cocoanut oil. Cocoanut-oil soap has a great affinity for water, hence frequently gives rise to dishonest practices, whereby fictitious weight is obtained.

Yellow soap is made by a mixture of resin with tallow and palm oil, or with a grease stock consisting of kitchen and bone fat. It is very firm, somewhat rough, and often translucent. *Toilet soaps* are varied in quality. They are commonly made from lard, beef marrow, or sweet almond oil, and after repeated refinings by

melting and powdering, finally scented with some perfume, such as the oil of roses, bergamot, mallow, lavender, verbena, rosemary, thyme, etc. Their colouring depends upon special pigments added to them. What is called Brown Windsor is an inferior soap of this kind, being made from the residue of refuse fats, scented with nitro-benzene or artificial oil of bitter almonds.

Glycerine soap is merely ordinary soap, to which glycerine has been added. The transparent soaps are made by drying ordinary soap in a stove, and then dissolving it in hot alcohol; subsequently this solution is filtered, the alcohol distilled off, and the residue run into moulds. *Silicated soaps* are ordinary soaps mixed with solutions of soluble glass or silicate of soda. These mixed soaps have exceptional cleaning properties, owing to the quantity of free alkali which they contain. Some of the so-called silicated soaps are mere mechanical mixtures of silicious substances, such as fine sand or fullers' earth, with ordinary soap; these are comparatively worthless.

Baths.—Water being a very much better conductor of heat than air, it rapidly abstracts heat from the body if much below the temperature of the latter, which is roughly 98° F. Owing to their physiological action being mainly dependent upon their temperature, the following classification of baths has been made:—

1. Those in which a healthy person feels neither hot nor cold; these are often called indifferent baths. Their temperature varies from 88° to 98° F. Some indifferent baths may be called warm baths, while those intermediate between warm and cold are often spoken of as tepid baths.

2. Cold baths, or those in which a healthy person feels cold. Their temperature varies from 32° to 60° F. If the bath is only moderately long and not very cold, the body heat remains constant, because the production of heat balances the loss. If much prolonged, there is an actual loss of body warmth. Cold baths greatly increase the tissue waste of the body.

3. Warm baths, or those in which a healthy person feels warm. Their temperature may vary from 100° to 103° F. A warm bath increases the body heat by both imparting warmth to it and preventing loss of heat from it. Some people, particularly the Japanese, use very hot baths indeed. Unless one has been gradually educated up to them, exceptionally hot baths should not be employed. Vapour and Turkish baths are varieties of the warm bath. The latter is practically the passing of a longer or shorter time in rooms at temperatures rising from 100° to 200° F.; during this period, the action of the skin is vigorously encouraged, and the body, after cleansing with soap and friction, gradually

hardened by sprayings of water passing from hot to cold, followed by a cold plunge and subsequent rest or detention in a cool room.

A short bath is usually followed by a sense of well being, due to the increased activity of and removal of waste products by the internal organs, consequent on the contraction of the superficial or cutaneous blood-vessels. The feeling of warmth, which so commonly ensues, and ought always to ensue, after leaving a bath, is probably to be explained by a reactionary dilatation of the vessels of the skin after their original contraction. If a bath has been too prolonged, or the person be at all enfeebled, there may be no subsequent feeling of warmth after bathing, due either to the cutaneous vessels not having contracted originally, or that, having contracted, they are unable to expand on leaving the bath, or have become paralyzed by cold. All bathers should take care not to in any way prevent the reactionary dilatation of the superficial or cutaneous vessels, by either remaining in a bath too long or using it at too low a temperature.

Cold baths, if not too cold, are particularly enjoyable, on account of the reactionary exhilaration which follows. Their regular employment is specially favourable for training the capillaries to alternately contract and dilate, and thereby render habitual bathers remarkably free from liability to catch cold.

It is a mistake to bathe either fasting or immediately after taking a full meal; and equally injudicious to do so when exhausted by fatigue. The best time for a bath is either early in the morning after a cup of tea or coffee and a biscuit, or an hour or so after breakfast. Persons advanced in years, and those in whom the circulation is weak, should neither attempt outdoor bathing nor indulge in very cold baths at home; in them the resisting and rallying powers are often low, and reaction correspondingly difficult to secure. A very hot bath, of 100° to 110 F., is often less depressing than a warm one of a lower temperature, as it stimulates both the skin and circulation. To avoid chills, such very hot baths are best taken at night. The following table indicates the approximate temperatures of water-baths, arranged according to popular designations:—

Very cold	32° to 50°F.
Cold	51° ,, 60°.
Fresh	61° ,, 75°.
Tepid	76° ,, 88°.
Warm	89° ,, 99°.
Very warm to hot	100° ,, 110°.

It must be remembered that no very precise division of baths can be made, as no two persons are equally sensitive to the effects of heat and cold.

Clothing.

The main objects of clothing are: (1) to protect the body from cold, heat, wind, and rain; (2) to maintain its warmth, protect it from injury, and also to adorn it. The chief materials used for clothing are derived from animals and vegetables. From the animal world we get wool, fur, leather, feathers, and silk; while from vegetable life we draw cotton, flax, jute, hemp, coir, indiarubber, and gutta-percha.

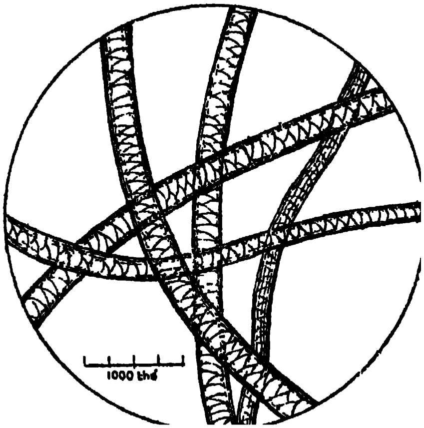


Fig. 66.—Wool under the microscope, taken from white flannel

Wool is a modified form of hair obtained from sheep, goats, camels, and other animals. Wool fibres (Fig. 66) have on their surface fine imbricated scales, which run in one direction, and give it a serrated or toothed appearance when examined under the microscope. In the finest wools, these serrations may number as many as 2500 to the inch. Wool is soluble in caustic alkalies, while vegetable fibres are not so. The wool from the Angora goat is known as mohair, and is largely used in the making of plushes, velvets, astrachans, and other fancy fabrics. Alpaca comes from the Peruvian sheep, a kind of llama. It is a very fine silky wool, and greatly used for shawls and umbrellas. Cashmere is a specially soft and fine wool from the Thibet goat; it is very expensive and difficult to get. Camel's hair is really a fine wool; it is now chiefly met with in the underclothing of Jaeger. Wool is largely used for the making of flannel, cloth, blankets, worsteds, and knitted goods. Felt is really wool made up without either weaving or spinning, the whole holding together simply by the cohesion of the serrated fibres.

Wool is the best material for underclothing; it conducts heat badly, and while absorbing moisture readily, gives it off slowly, so that far less cooling is produced by evaporation from the woollen garment than from any other. It has the disadvantage of hardening and shrinking on washing.

Furs.—These are the skins of certain animals from cold

countries, which have, in addition to their long "overhair," a dense hairy covering called fur. The chief are bear, seal, chinchilla, ermine, and Russian sable or marten. Fur is often used for making felt; hat felts are chiefly made by compression under heat and moisture of the fur from horses and rabbits. The coarser felts used for carpets are made from cow-hair.

Leather.—The skins of animals, if appropriately prepared by tanning, tawing, or shammoying, are rendered tough, yet soft and fit for use by man as clothing. The chief skins so used are those of the ox, sheep, horse, and goat. *Tanning* is the steeping of a skin in an infusion of oak bark or other substances rich in tannic acid. By this process, insoluble tannates of the gelatin and albumin of the hides are formed. To be properly carried out, tanning takes nearly a year. *Tawing* is the same process as tanning, except that mineral astringents such as alum and bichromate of potash are used in place of the vegetable product, tannic acid. Tawing is more rapid, but yields an inferior and harsher leather than tanning. *Shammoying* is the impregnating of a skin with fish oil: it is chiefly applied to light skins, and is the process by which chamois leather is prepared.

Feathers are not much used for actual clothing, but rather as ornaments. Their employment is still considerable for stuffing pillows and beds. These latter, if not made too soft and luxurious, are quite as healthy as any other bed.

Silk. This is the strong fibre produced or spun by the caterpillar or larval stage of certain moths. The silk threads are formed in two small glands situated on the under part of the body and opening by a duct on the lower lip; the silk serves as a protecting sheath or covering, called a cocoon, for the silkworm when about to assume the chrysalis stage. The silk thread so ejected by each worm and wound into a cocoon, measures some 4000 yards in length and consists of two fine filaments, one from each gland, laid side by side and agglutinated together into a single thread or fibre. The best silk is produced by the larva of the moth called *Bombyx mori*, or Chinese silk-moth. Other kinds of silk are spun from other silkworms closely allied to the *B. mori.* There are the *B. textor* and *B. fortunatus*, common in Bengal; the *B. crœsi*, found in Madras; the *B. arracanensis*, met with in Burmah; and the *B. sinensis*, belonging to China. All these are mulberry feeders. The caterpillar of another moth called *Antheræa pernyi*, found in Mongolia, and which feeds on oak leaves, spins the kind of silk known as tussur silk. The *A. mylitta* is another variety of the tussur silk-moth, common in India. It feeds on bher trees and other shrubs. Similar moths are found in Assam and Japan.

The silk fibre (Fig. 67) consists of a central core or fibre, covered with a waxy and albuminous colouring matter. Microscopically, silk fibres are structureless and glass-like, usually measuring some $\frac{1}{2000}$ inch thick, and without surface markings or scales. Silk is insoluble in water, alcohol, and ether, but dissolves in very strong alkalies, mineral acids, and acetic acid. It is readily distinguished from wool or other animal fibre by the action of an alkaline solution of lead oxide, which, owing to the presence of sulphur in wool, darkens it, but does not affect silk. Silk is distinguishable from vegetable fibres by being stained yellow by picric acid, which they are not. The average cocoon yields some 500 yards of workable silk, which in its manufactured form is either reeled or spun silk—this latter being prepared by carding or spinning from the waste and spoiled cocoons. During its manufacture into fabrics, silk fibre is largely altered, expanded, weighted, and dyed by various reagents, notably salts of tin and iron, which render the term "silk," as applied to actual articles of clothing, a more or less conventional expression of what something is meant and ought to be. Silk is mainly used in the manufacture of satins, silks, plushes, velvets, ribbons, crape, and in a few woollen goods to give them lustre. Silk is very absorbent of moisture, and is a non-conductor of electricity.

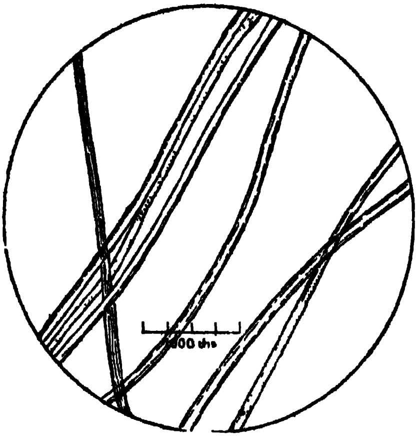


FIG. 67.—Silk from a silk thread.

Cotton is the downy hair of the seeds of plants belonging to the family Gossypium, of the order Malvaceæ. The cotton fibres consist mainly of cellulose, and vary from a half to one inch in length. The fibres are freed from the seeds by machinery, and, after being cleaned and spun into yarn, are woven into fabrics, which, after being bleached, are "finished" for the market. This finishing process usually involves mangling, starching, and damping, and often includes filling up the interstices between the fibres with compounds to give weight and a false appearance. Cotton is largely made up into sheeting, calico, towelling, jean, fustian, velveteen, flannelette, and paper. When mixed with wool, it

constitutes the merino of vests, socks, and many fancy materials; it is also mixed with silk or the cheaper kinds of silken goods.

Cotton filaments (Fig. 68) average about $\frac{1}{1000}$ inch thick, are flat and ribbon-like, and always recognizable by being twisted. Cotton is very durable, does not shrink when washed, absorbs moisture badly, and rapidly conducts heat away. On this account it is ill adapted for under-garments next the skin, as, if perspiration be present, it readily induces chill. What is called "cellular cotton" is merely an ordinary cotton fabric with larger interspaces than usual in its texture. These being filled with air, which is a bad conductor of heat, cause this material to be somewhat warmer than the ordinary cotton, and a greater protection to the body against sudden changes of temperature. Similar advantages attach to "Airlin" and the various "mesh fabrics" now in the market.

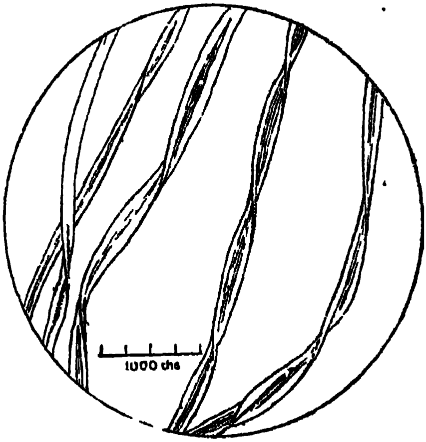


FIG. 68.—Cotton from flannelette

Flax is a fibre obtained from the stalks of a plant called the *Linum usitatissimum*, which grows to a large extent in Russia and Ireland. The seeds are the familiar linseed, from which the meal of which poultices are made is prepared, and, too, from which linseed oil and cake, the cattle food, are produced. The stalks, after being allowed to ferment or rot on the ground in the damp, are beaten and combed until

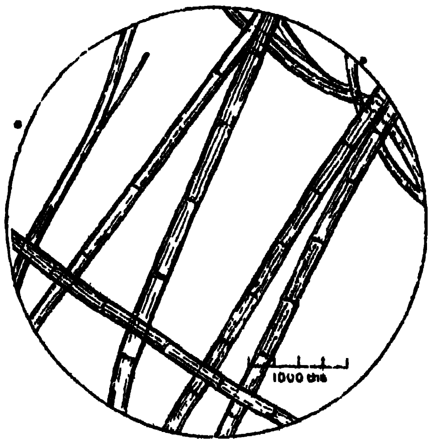


FIG. 69.—Linen, from table-cloth of Irish linen.

something like 6 per cent. of saleable flax fibre is obtained from the plant. The flax fibres (Fig. 69), when seen under the microscope, are marked by transverse striæ at regular intervals; they are not flat like cotton, but more like silk, only they show a fibrous and jointed structure which is not met with in silk. Flax is much more expensive than cotton, and is used chiefly for the manufacture of linen, cambric, and lawn. Linen resembles cotton in being a good conductor of heat and a bad absorbent of moisture. It is in many respects even inferior to cotton for underclothing, but from its smoothness and lustre is unequalled as a material for collars, cuffs, and shirt-fronts. Weight for weight, flax fibre is stronger than cotton, in the ratio for single yarn of 3 to 1·8, for double yarn as 3 to 2·25, and for cloth as 3 to 2·1.

Jute is a brittle and very hygroscopic fibre obtained from the *Corchorus capsularis*, a plant growing chiefly in Bengal. Jute is not much used for clothing except as an adulteration of silk and in the making of false hair; it is chiefly employed for coarse fabrics such as mats, cheap carpets, sacking, curtains, and table-covers. It is used also as a backing for floorcloths.

Hemp is another fibre not much used in European countries for clothing. It is a coarse fibre, prepared from the stem of the *Cannabis sativa*, a plant growing in Europe, Asia, and America. It is prepared like flax and jute, and chiefly used for rope, yarn, canvas packing, and sail cloth. The Indian plant yields a narcotic drug, while hemp-seed is a popular food for birds.

Coir is a coarse, tough, harsh, yet light fibre obtained from the husk of the cocoanut. It is rarely used for clothing, but largely so for making mats, brushes, and ropes.

Indiarubber enters largely in the present day into the constitution of our clothing, chiefly because it is elastic and impermeable to water. Under the name of caoutchouc, it is the milky juice of several plants growing in Africa, Asia, and South America. Caoutchouc is a somewhat complex body, dissolving in chloroform, ether, petroleum, benzene, and carbon disulphide. Freezing impairs its elasticity, while great heat softens and melts it. Fats also destroy it. When steeped in melted sulphur at 140° C., caoutchouc becomes vulcanized. Macintosh cloth is merely a cotton or silk fabric covered, layer by layer, with a solution or paste of caoutchouc. Guttapercha is, like indiarubber, the juice of certain trees; but these grow only in the Malay peninsula. Excepting as boot soles, guttapercha is little used in clothing.

Warmth and coolness, or the power of maintaining the body heat at its normal height, being the most important property of all dress materials, it follows that our choice of clothing will depend largely upon this feature. How far a given clothing will

give warmth depends upon its material, its texture, number of layers, and its colour. Owing to fabrics conducting heat in the following order from highest to lowest, namely, linen, cotton, silk, feathers, fur, and wool, it follows that wool, fur, and feathers are the warmest materials, then silk and cotton, while linen is the coolest. The more readily a material conducts heat, of course, the cooler it feels. This heat-conducting property is mainly proportionate as to how close it is woven, and as to how little air it contains. On this account, all soft, furry fabrics, no matter whether of wool or cotton, always feel warmer than the closely woven, smooth-surfaced silks and linens. In the same way, the more layers of clothing there are, the more layers of air there are retained between them. The influence of colour is dependent upon the heat-absorbing powers of that colour. White absorbs heat the least, and is consequently the coolest; then comes yellow, red, green, blue, and black. It is obvious this effect of colour can only be of influence when outside, and that the popular idea that red flannel, when worn next the skin, or as part of an undergarment, is warmer than white is imaginary. It is a mistake to wear coloured clothing next the skin, as not unfrequently the dyes are poisonous, and, coming off, give rise to skin diseases.

While affording warmth, protection from cold, wet, and injury, clothing should always be so made as not to in any way impede natural movements, nor unduly constrict any part of the body, nor be needlessly heavy, and also not afford unnatural support. The more we analyze the common forms of clothing, the more we see that their main faults are in the direction of impediment, constriction, and weight. This is particularly emphasized in the case of long and close-fitting skirts, tight sleeves, stays, garters, bands round the waist and neck, ill-fitting gloves, hats, and boots. Many of these defects and faults would be obviated if people would remember that (1) no article of clothing should be either so tight as to interfere with the circulation, or so shaped as to change the natural outline of any part of the body; (2) no garment should contain more material than is actually necessary; (3) all garments requiring suspension should be suspended directly or indirectly from the shoulders or hips.

It is probably in the attire of children attending school that the greatest need of a neat hygienic dress is manifest. For girls we would suggest that each should wear a flannel chemise, blue serge knickerbockers fitted to the waist with an elastic band, and no stays of any kind. Next we would suggest a woollen jersey, and an overdress with shoulder straps fastened into the waist with a loose belt. In summer the jersey might be left off, and a cotton

blouse substituted. For out-of-doors, probably a flannel hood would be the best head-covering in winter, while in summer a head-covering is hardly needed in our climate. Such a dress as this would be not only neat and healthy, but by its smartness would raise the moral tone and help to give the self-respect which is so often lacking in children.

When possible, underclothing should be of wool in this country; in the tropics this is too heavy a material, and linen or cotton shirting is more generally suitable. The Chinese habit of wearing a net next the skin in hot weather, with a thin silken garment over the net, is a good one.

Probably no article of attire is more faulty than the boot. A properly made boot should fit the foot accurately; the great toe should be in a straight line with the inside of the foot; the shape of the sole of the boot should be taken by drawing a pencil round the outline of the foot when the weight of the body is resting on the foot, as in standing, so that the sole may be big enough to support the fully expanded foot; the material should be of soft and flexible leather; even when new, the wearer ought to be able to move all the toes with freedom in the boot; the heel should be broad and low. The stocking or sock should, whenever possible, be of a woollen material or a mixed material in which wool predominates. If no sock be worn, the boot needs to be high and close-fitting round the ankle, so as to prevent dust and stones getting into the boot. The sole of a boot should be wider than the foot, and if the boot is meant for hard wear, the excess of breadth in the sole should be considerable, so as to serve as a protection against loose stones.

EXERCISE.

It may be said with truth that the chief condition of health is exercise in the open air, and those who have the most of it are the healthiest. The desire for physical exertion and muscular exercise is a natural instinct; the very restlessness of the young child and of school children shows this. Our bodies possess the peculiar attribute that the more they are used, within reasonable limits, the stronger and more vigorous they become. Every one is familiar with the fact that a disused muscle wastes, becomes fatty and wanting in blood, whereas one which is judiciously used and exercised, grows, thickens, and becomes in every sense stronger. But mere exercise involves not only growth and development of the ordinary muscles of the limbs, it means also the healthy use of the heart muscle, of the muscles of respiration, of the muscular tissue of the arteries, and of the muscular

elements of all parts which are capable of movement. To these must be added an increased activity of the brain and nervous system, along with a stimulation of both secreting and excreting organs.

Upon the circulating system, the effect of exercise is to rapidly increase the force and frequency of the heart's action with a consequential augmented flow of blood throughout the whole body. A healthy heart, during moderate exertion, though often beating rapidly and forcibly, does so regularly and equally; but if embarrassed, or the exercise be severe and prolonged, its pulsations may become small, quick, unequal, and irregular. A deficiency of exercise leads often to a weakening of the heart; but, on the other hand, exercise or unaccustomed exercise, suddenly and long continued, may lead to palpitation, valve disease, or other heart affections. These may be usually obviated by careful training and judicious rest. Sudden and violent exercise should be avoided by those with diseased hearts, and by those advanced in years, as in them often the circulation is unable to suddenly adapt itself to the new conditions set up.

On the lungs, the effects of exercise are to not only increase the rapidity of breathing, but also to considerably increase the amount of air inspired and the carbon dioxide expired. Thus, while a man at rest draws into his lungs about 480 cubic inches of air per minute, when walking three miles an hour he draws in 1550 cubic inches, and if doing six miles an hour inspires 3260 cubic inches. Simultaneously with this, the amount of carbon dioxide and watery vapour in the expired air are increased. During exercise, the elimination of carbon is enormously increased, a fact which explains the instinctive desire of men making exertion and not restrained in the choice of food, for the various fats or hydrocarbons with a small amount of starch. When exercise is excessive or badly arranged, the circulation through the lungs may become impeded and the breathing laborious. The knowledge of this fact suggests the need to watch the action of the lungs of all men being trained for prolonged exertion.

Under exercise, the voluntary muscles grow harder and become more responsive to the will. If continuously over-exercised, their growth may change to actual wasting, due to damaged nutrition of their fibres, following either the accumulation in them of the products of their own action, or the exhaustion of their supply of oxygen; possibly both.

Provided it be not pushed to such an extreme as to leave no time for cultivation of the mind, there can be no doubt but that exercise is quite consistent with, and eminently favourable to, high mental attainments and activity.

The effects of exercise on digestion are such that it stimulates a desire for meat, fat, and salt, and in a less degree one for carbohydrates. The abdominal viscera act more vigorously, and the whole digestive processes are increased. The actual amount passed by the bowels during exercise seems to be slightly lessened, possibly due to less water entering the intestines.

Owing to the action of the skin being so much increased during exercise, the water and chloride of sodium of the urine diminishes; on the other hand, the uric acid, pigment, and sulphuric acid are augmented. The urea, however, is little affected; while the actual total nitrogen excreted is, if at all increased, only so in the period of rest succeeding exertion.

The exact amount of exercise which a person takes is entirely a matter of individual decision; while what amount a healthy adult should take is not easy to fix, as a hard-and-fast rule would not fairly apply to all the varying degrees of health and strength.

Work is always expressed in units of weight lifted through a unit of height; as in terms of pounds lifted a foot, or tons lifted a foot. A fair day's work for a man of average weight and height is generally taken to be about 300 foot-tons, or the work necessary to raise 300 tons one foot high; this has been calculated to be equivalent to walking about 16 miles in a little over five hours. A hard day's work is about 450 foot tons, equal to walking some 24 miles in eight hours; and an extremely hard day's work is from 500 to 600 foot-tons, equal to walking 26 to 32 miles in nine or eleven hours respectively. For average men, engaged in sedentary occupations, not less than 100 to 150 foot-tons of work or exercise should be performed each day, equal to walking for two hours at a moderate pace, or equal to raising the body-weight through some 500 to 600 yards in height. It is not easy to say what the work done is in mental and office work generally. These rules, it must be remembered, apply only to healthy adults, and need to be much modified in the case of young children, or those whose age or health prevents their exercising their full powers. In children, much of their power and energy goes in building up the growing body, and consequently less exercise or work can be expected of them. Thus, a child, weighing 80 lb., ought not to be called upon to do half the work done by an adult weighing 160 lb., but something less, probably in the ratio of the square of their respective weights. In a similar manner, women should not be called upon to do as hard or even harder work than the men.

No mention has been made of the internal work of the body, such as that of the heart, respiration, digestion, etc. This has

been variously estimated; but adopting a mean, we get about 260 foot-tons for all the internal mechanical work; which, added to the external labour, makes the demand, for the average person, to be about $\frac{1}{7}$ of all the force obtainable from the food consumed.

Much of our knowledge concerning the work done by human beings, at various speeds of walking, we owe to the Rev. Dr. Haughton, of Dublin, who finds that at about 3 miles an hour, the work done in walking on ordinary roads is equal to $\frac{1}{20}$ of the work done in direct ascent, or that a man walking 20 miles on the flat, at 3 miles an hour, does as much work as if he had raised his body through a mile in height. The fraction $\frac{1}{20}$ is the expression of the resistance due to traction, and varies with the velocity at which the work is performed; being $\frac{1}{38}$ for a velocity of 1 mile an hour, $\frac{1}{26}$ for 2 miles an hour, $\frac{1}{16}$ for 4 miles an hour, and $\frac{1}{14}$ for 5 miles an hour.

When a man goes up a height, he raises his whole weight through the height he ascends, and to compute the quantity of work done we must multiply the weight by the height, and an easy calculation changes this into the weight raised 1 foot.

The formula for the calculation of work done is usually written thus: $\frac{(W + W') \times D}{2240} \times C =$ foot-tons; in which W is the weight of the person, and W′ is the weight carried, both expressed in pounds; D is the distance in feet; C is the coefficient of resistance or traction; while 2240 is merely the number of pounds in a ton. The application of this formula will be more readily understood from the following examples.

Let A and B be two men. A lifts a 10-lb. hammer, $4\frac{1}{2}$ feet high, 12,000 times in eight hours. B, who weighs 10 stone, walks 14 miles on an ascent of 1 in 300 in six hours, carrying 30 lbs. on his back. It is required to know which does the harder work, and by how much.

Applying the formula to the case of A, we get $\frac{10 \times 4{\cdot}5 \times 12000}{2240}$, which, worked out, gives 241 foot-tons of labour done in eight hours.

B's case is somewhat more complicated. It involves two small calculations, one for the work done, had it all been on the flat, the other for the additional labour involved in going uphill, which is equivalent to lifting his own and load's weight a given height. The sum of these two will give his actual work done. Using the formula, we get B's work on the flat to stand thus, after reducing the stones to pounds and the miles to feet—

$$\frac{(140 + 30) \times 14 \times 5280}{2240} \times \frac{1}{20} = 280\tfrac{1}{2} \text{ foot-tons}$$

As the rise is 1 in 300, we get for the second part of the statement, the lifting of the man's body-weight and load, a height of

$$\frac{14 \times 5280}{300} = 246{\cdot}4 \text{ feet, or } \frac{(140 + 30) \times 246{\cdot}4}{2240} = 18{\cdot}7 \text{ foot-tons.}$$

Then adding these two results together or $280{\cdot}5 + 18{\cdot}7 = 299{\cdot}2$ foot-tons as the work B does in six hours.

In attempting to compare B's work with A's, we must allow for the fact that B does his in $\frac{3}{4}$ the time that A took, or six hours as compared with eight hours. Therefore, to obtain a fair comparison, we must multiply B's work of 299 foot-tons by 4, and divide by 3 or $299 \times \frac{4}{3} = 398$ foot-tons of labour performed by B, while A only did 241 foot-tons, or 157 foot-tons of work done by B more than by A, if both had been working at the same speed.

CHAPTER VII.

INFECTION AND DISINFECTION.

EVERY one is now familiar with the fact that certain common diseases are due to the entrance within the body from without of certain definite poisons or ferments; which, having once entered the body, appear there to be able to both grow and multiply. Owing to the poison, after growing and increasing within the body, being capable of being given off again from the body, these diseases are communicable from one person to another, and, as such, are said to be *infectious*; while the actual poison or disease-matter itself is spoken of as the infective agent or *infection*. As the result of improved methods of observation and study, it has, in the case of several of these infectious diseases, been possible to recognize and determine that the actual disease-producing matters or infective agents are minute forms of life, consisting apparently of a single cell, and that all infectious diseases are probably nothing more nor less than the result of the spreading and development within the human body of these small living cells.

Existing as they do upon the very borderland of the vegetable and animal kingdoms, these minute organisms have given rise to much controversy, not only as to whether they really belonged to the vegetable or animal world, but also as to what they should be called. It is now very generally recognized that they are minute

vegetable cells, though their true position among the plants is still unsettled; and are indifferently spoken of as "microbes," "micro-organisms," "microzymes," "bacteria," "germs," or "contagia." No matter how called, all microbes consist of an external covering of cellulose, and an internal living substance called protoplasm, which is quite destitute of chlorophyll or vegetable colouring matter. It is owing to the absence of this green colouring matter that microbes, though vegetable cells, differ from the higher plants in being unable to decompose atmospheric carbon dioxide, in which feature they closely resemble the fungi. On the other hand, they differ from animal cells in having a cellulose covering, and by being able to derive their nitrogen from nitrogenous compounds, such as ammonia and nitric acid.

Microbes vary considerably in form, being either round, oval, rod-shaped, spiral, or filamentous. The round or oval-shaped ones are termed *micrococci;* the rod-shaped, *bacteria*, *bacilli*, and *vibriones;* the spiral forms, *spirilla;* while the filamentous forms are generally termed *leptothrix* when straight, and *spirochæta* when wavy. Some microbes are provided with flagella or lashing tails, by which they move, while others are devoid of these appendages. The size of these micro-organisms is, of course, very small; their dimensions, as a rule, varying from about 0·0005 millimetre to 0·05 millimetre in length or breadth; that is, in English measures, something like from $\frac{1}{50000}$ to $\frac{1}{500}$ inch.

Microbes multiply or propagate usually by fission or division, while a few increase their kind by means of spores or eggs. These spores are very resistant to all outside influences, and are able to withstand treatment such as boiling for a few minutes, a procedure which readily kills the parent forms. Warmth and heat favour the growth and multiplication of all kinds of micro-organisms; thus, within an hour, under suitable warmth, a single bacterium divides into two parts, then again in another hour into four, after three hours into eight, and so on until, after twenty-four hours, it has been calculated that the number resulting from a single original one will exceed sixteen millions. It is only by the consideration of facts like the foregoing that the theory and true conception of the nature of infectious diseases can be understood. These diseases are caused and spread by a process resembling the sowing of seed upon a suitable soil, in which, by reproduction of the seed, it, in its turn, becomes a new centre or focus of material whence it may spread and extend to others. A good example of this sequence of events is seen if we sow a little yeast into a solution of sugar. Yeast, we have already learnt, consists of nothing more than innumerable microscopic plant-cells; these, on being placed in the

sugar, set up fermentation, by which the sugar is split up into carbon dioxide which goes off into the air, and alcohol which remains, while at the same time an enormous increase has taken place in the number of yeast-cells. If we substitute for the sugar solution the human body, and for the yeast-cell the microbe of an infectious disease, such as diphtheria, enteric fever, cholera, or small-pox, we can readily appreciate the analogy between the process of fermentation and infectious-disease production, and, too, understand that as fresh yeast-cells (only too ready to commence their fermenting action) are produced in the sugar solution, so are new disease micro-organisms formed in the body, ever ready, in their turn, to reproduce, on gaining access into another, all the features and peculiar characteristics of their own disease. The close likeness between fermentation and infectious disease processes has led to the term *zymotic* diseases (from ζύμη, a leaven) being applied to them. The chief infectious diseases affecting man are cholera, chicken-pox, diarrhœa, diphtheria, erysipelas, influenza, measles, mumps, scarlet fever, small-pox, enteric fever, typhus fever, tuberculosis, and whooping-cough.

If the above conception as to the nature of infectious diseases be correct—and there is every reason to believe it is so—that infection matter is living matter in the form of a primitive plant-cell capable of growing and increasing within the bodies of men and animals, the course of an infectious disease is truly the life-history, so to speak, of a lower plant, and as such has a period of development, a period of its greatest vigour, and a period of decline or death. The time of development, or as it is usually called, the period of *incubation*, is a most important feature in all diseases; so, too, is their duration or length of time during which the sick person is liable to be a source of infection to others. Varying, as they do greatly, an approximate idea of their periods of incubation and infectivity is given in the table on the opposite page; but it must not be forgotten that occasionally remarkable exceptions to these averages occur.

The incubation period is that which elapses between actual infection and the appearance of the first signs or symptoms of the disease. In some diseases, as in small-pox, it is almost always of the same length. It is an important fact to know in connection with all infectious diseases, inasmuch as it enables us to say, when a person has been exposed to infection, that after the lapse of a certain number of days, if not already attacked, that person is safe, and may mix with other people without risk to them. At present we know very little about the changes which take place in the body during incubation, beyond that the poison is multiplying in some part of the system. The majority of these

diseases have a short and limited course, ending either in death or recovery more or less complete. A few, like chicken-pox, mumps, and German measles, are remarkably mild in their symptoms; but, on the other hand, a few are liable to vary greatly in their intensity. This is particularly so with both scarlet fever and small-pox. A general rule seems to be that severity or mildness holds good for the majority of cases occurring in a given outbreak, but that the severer cases are more common in the earlier part of an outbreak than in the latter. Age, sex, race, and season also have an important influence upon the severity of infectious-disease attacks. Many curious facts relating to the peculiar action of the causes of these diseases upon the human body could be related; how in some cases only people of a certain age or sex suffer, while in others the attacks and deaths are largely confined to those of certain descent or parentage. These and many other points connected with infectious diseases are still but imperfectly understood.

Disease.	Period of incubation.	Duration of infectivity.
Chicken-pox	10 to 14 days	3 weeks.
Cholera	1 to 5 ,,	3 ,,
Diphtheria	1 to 8 ,,	6 ,,
Diarrhœa	1 to 4 ,,	1 to 2 ,,
Enteric fever	8 to 14 ,,	6 ,,
Erysipelas	1 to 5 ,,	1 ,,
Influenza	1 to 4 ,,	3 ,,
Measles	8 to 20 ,,	4 ,,
German measles	6 to 14 ,,	3 ,,
Mumps	14 to 22 ,,	3 ,,
Scarlet fever	1 to 6 ,,	6 to 8 ,,
Small-pox	12 ,,	6 ,,
Tuberculosis	unknown	During the whole disease.
Typhus fever	6 to 14 ,,	4 weeks.
Whooping-cough	4 to 14 days	8 ,,

Immunity and Protection.—Perhaps the most striking fact in connection with infective diseases is the variability in susceptibility to disease conditions exhibited by different persons. Equally remarkable is the fact that insusceptibility to one of these diseases may be acquired by an attack of the same disease or by inoculation of the specific organism, or its products, standing in causal relation to the disease. In other words, non-susceptibility, *i.e.* immunity to a disease, may be *naturally* possessed by a human being, or it may be *acquired* either by passing through an attack of the disease or by artificial means of inoculation.

Natural immunity is the inherent ability of the body tissues

to either destroy the invading bacilli or neutralize their toxins. This natural resistance to the invasion of disease-producing germs or their products may be a racial condition, a family condition, or simply an individual condition. It, further, may be destroyed or certainly weakened by a variety of circumstances, such as changes in food or mode of living, under exposure, confinement in the house, or other modifications in environment, conducive to a lowering of the general vitality of the body.

Acquired immunity may be (1) that induced by recovery from a previous attack of a disease; (2) that induced by an attack of an allied disease, as in the immunity conferred by vaccinia against variola; (3) that induced by the injection of antitoxic substances, as in diphtheria; (4) that induced by the injection of toxins, as in the protection against enteric fever and plague by means of dead cultures of the specific organisms of those diseases. The first two forms of acquired immunity are often spoken of as active immunity, while that conferred by toxin and antitoxin is designated passive immunity. This latter form of immunity is usually of short duration.

Various theories have been offered to explain the phenomena of acquired immunity. Thus, Pasteur's "exhaustion" theory assumed that through the growth of the bacteria in the organism they destroyed some substance essential to their life, and so made subsequent growth of the same species impossible in such an organism. Another theory, known as the "retention" theory, was proposed by Chauveau, and assumed that some product of the vital activity of the bacteria was retained in the organism, which was prejudicial to the subsequent development of the same species. Neither of these theories afford a satisfactory explanation of acquired immunity. In order to explain both natural and acquired immunity, Metchnikoff advanced the theory of phagocytosis, according to which the resistance of an animal to bacteria depends on the activity of certain cells called phagocytes, which take up bacteria into their interior, and so destroy them. The ingestion of the microbes by the phagocytes is explained on the hypothesis that the chemical substances elaborated by the bacteria attract the former; if they fail to do so, then the bacteria remain free to multiply, and general infection occurs. It is possible that phagocytosis may be the result rather than the cause of immunity; the theory certainly fails to satisfactorily explain the process of immunization against a toxin. In direct opposition to Metchnikoff's theory is that of Buchner, which claims that the pathogenic bacteria are destroyed within the body by the bactericidal action of the blood-plasma and not by the leucocytes; in other words, the essential factor is humoral rather than cellular. Buchner has

applied the term alexin to this hypothetical bactericidal proteid substance of the blood and body fluids. Certain experiments of Pfeiffer, in which he demonstrated that if an animal was rendered immune to cholera, and then received an injection of cholera organisms, the injected organisms underwent rapid deterioration, and were completely destroyed, suggested the view that immunity against bacterial invasion was not due to protective substances normally present in the body, but to something which had developed during the course of immunization. This is the theory of antitoxins, which antitoxins are neutralizing agents formed within the body as the result of the vital activities of the body-cells called into action during immunization.

The difficulties in the way of explaining immunity by any one of these theories are great. Undoubtedly the main point is that the French school attributes to the leucocytes a more important *rôle* than that admitted by the Germans; but, possibly, this divergence of views arises from a too rigid adherence to the conception that immunity is always either bactericidal or anti-toxic. All practical experience in the case of the common infective diseases shows it to be neither bactericidal nor anti-toxic, but that it is brought about by the coalition of both cells and serum. An interesting attempt to reconcile the conflicting theories as to immunity is the hypothesis of its mechanism put forward by Ehrlich: its very general acceptance by present-day workers demands a short summary of its essential features.

Many experiments with bacteria show that the toxins of different species have an especial affinity for the cells of different organs or parts of the body: further, when the amount of poison entering the body is insufficient to destroy the cells which have a special affinity for it, these cells are only injured to such an extent as to permit of repair. Ehrlich conceives the cells of the body as having a complex structure which may be described as being a central mass or nucleus from which radiate a number of bonds or side-chains, each of which seems to bind the cell to other substances. Assuming that a cell has a special affinity for a particular toxin, the combination of the toxin with the cell disturbs its physiological balance leading to a reproduction or repair of damage. The reproduction tends to be carried to excess. The excess finds its way into the blood-current, and is there capable of combining with further toxin, and so preserving other cells from injury. The excess of so-called side-chain is really the antitoxin, and its union with the toxin results in the formation of a compound which is physiologically inert. Ehrlich recognizes three types of immunity which differ in their mechanism according to the nature of the substance used in the act of

immunization. His work upon hæmolysis revealed the fact that the blood-serum of an animal, immunized against a different blood to its own, lost its hæmolytic power if heated to 56° C. for half an hour, but could be re-activated by a drop of normal blood-serum. This fact shows that the hæmolytic power of the immune serum was due to two substances, one present in normal blood but destroyed by a low heat, the other present only in the serum of the immune animal. The latter he called the "immune body," and the former the "complement," because of its complementary action. In his later work Ehrlich speaks of the immune body as an amboceptor, a term indicative of its possessing two combining arms, one uniting it with the complement, the other with the blood-cell, bacterium, or whatever the animal has been immunized against: in other words, this amboceptor is specific for the particular cells employed in the act of immunization--that is, if immunized with red blood corpuscles of another species, one receptor or arm unites with the erythrocytes of that species, and the other arm unites with the complement, and so brings about hæmolysis or solution of the corpuscles. The same effect follows when the serum of an animal immunized with enteric bacilli is mixed with such organisms; this destruction or solution of the bacteria constitutes bacteriolysis. Hence we may speak of hæmolytic sera or bacteriolytic sera. In both these sera the receptors are spoken of by Ehrlich as being of the third order. In the immunity conferred by toxins, when antitoxins are formed, Ehrlich conceives the receptors to be of the simplest nature, possessing only one bond of attachment to which the toxin unites; these receptors or uniceptors he regards as of the first order. If we immunize an animal with a substance like milk, there forms in the blood of the immune animal a substance which exerts a coagulating effect when mixed with milk of the same species with which the immunization was induced. The receptors which bring this about differ from those of the first order, in that they possess, in addition to their combining element, an enzyme-like part which brings about the coagulation. This form of receptor constitutes Ehrlich's second order. We have reason to believe that normal blood contains a multiplicity of complements; but, according to Ehrlich's hypothesis of the mechanism of immunity, the prehensile parts of the amboceptor and complement must fit each other like lock and key; if otherwise, they cannot unite. Fortunately, the human complements conform to those of many animals, hence animals of this character lend themselves readily to the purpose of preparing immune sera.

For securing immunity and to discover means for preventing the action of disease-producing bacteria, much work has been

done by means of the serum of immune animals, or by the metabolic products of certain micro-organisms. This has been especially the case in respect of diphtheria, tuberculosis, anthrax, and enteric fever. Horses immunized with diphtheria bacilli yield an active antitoxic serum which is not only curative when injected into persons suffering from the disease, but is also a definite preventive agent when injected into those who have been exposed to infection. Although the protection afforded by this serum is of rather short duration (three weeks), it is sufficient to serve as a valuable aid in checking the extension of the disease among crowded institutions. The results obtained so far by using the products of tubercle bacilli in the treatment of tuberculosis have not been so successful, but, as a diagnostic agent, the tuberculin of Koch is valuable for the discovery of the presence of the disease in the early stage in both animals and man. Used in this manner, it is an important agent for the early discovery of the disease in cattle, and indirectly limiting the chances of the dissemination of the disease through milk and milk products. Somewhat similar results have been obtained in the prophylactic treatment of cattle with weakened cultures of the anthrax bacillus; while the results obtained among men, inoculated with killed cultures of the enteric bacillus, warrant great hopes of a definite and reliable means being elaborated for rendering young soldiers and others immune or refractive to this ubiquitous disease. The application of the same method has been distinctly encouraging as against cholera and plague; but in no disease have better results been obtained than in hydrophobia or the disease resulting from the bite of a mad dog or wolf. When a person is so bitten, particularly if on the bare skin, he is almost certainly inoculated with the germs or poison of hydrophobia, and which, unless treated by Pasteur's method, generally causes the death of the person bitten. Fortunately, the germs of rabies or hydrophobia take some weeks, often months, and occasionally a year or more, to incubate within the human system before they produce the disease; and when they do develop, they produce in the infected person or animal a substance which is capable of protecting from a future attack. Pasteur found that rabbits affected with hydrophobia yielded this protecting substance or fluid, and if this were injected into man before the germs from the bite had had time to propagate, the disease could be warded off and prevented from developing itself. Owing to the peculiarly long period which usually elapses between the infection and the outbreak of hydrophobic symptoms, ample time is given for the body to be saturated with the protective fluid before the poison of the disease begins to act and multiply.

Vaccination.—The best method of combating infectious diseases will probably be found in the direction of an extension of a practice analogous to that of vaccination against small-pox. This procedure is practically that of inoculating the human being with the lymph or infection juice of small-pox after it has passed through the body or blood of the calf; the result being the infecting of the human body or being with a mild form of disease which, while giving rise to little or no physiological disturbance, renders man more or less insusceptible of true and original small-pox.

In the case of small-pox, the incubation being so much as twelve days, as compared with eight days of incubation for vaccination, it is possible by vaccinating a person within the first three days after exposure to infection to modify and possibly prevent small-pox from developing. Many cases have occurred in which this has been successfully done; thus, suppose an unvaccinated person be exposed to small-pox infection on a Sunday, and be vaccinated on the following Tuesday, the vaccination, if efficiently performed, may prevent the development of the small-pox. If the vaccination were put off till the Wednesday, small-pox would probably appear only mildly and much modified; but if no vaccination took place till the Thursday, then the disease in all probability would develop fully, owing to the vaccine matter being unable to catch up, as it were, the small-pox poison, and so affect the system first. Instead of waiting, however, for exposure to small-pox infection to take place before seeking protection by means of vaccination, it is better to be vaccinated beforehand. The law requires every child that is born to be so protected by vaccination before the age of six months—unless (*a*) the parent obtains a magistrate's certificate of exemption, or (*b*) the child dies, or (*c*) is attacked by small-pox within that period, or (*d*) three or more unsuccessful attempts at vaccination have been made, or a medical certificate of postponement (for not more than two months at a time) is given on the ground of ill-health, or of recent prevalence of infectious disease in the district, or of the condition of the house in which the child resides. The parent is relieved from the obligation to have the child vaccinated, if within four months after it is born he satisfies a magistrate that he conscientiously believes that vaccination would be prejudicial to the health of the child, and within seven days thereafter gives the magistrate's certificate to the vaccinator. Some people object to the law as interfering with the individual rights of the citizen; it is not in any way intended to do that, but rather to protect the community or mass of the people from what is a very great danger, namely, the occurrence and increased intensity of small-pox among unprotected persons. In vaccination, carefully and cleanly

performed, and with pure lymph, we have an undoubted means of protecting the race against a horrible, loathsome, and fatal disease. Public vaccinators are to use only glycerinated calf-lymph, or other lymph supplied by the Local Government Board, and must keep registers from which the origin of the lymph used in each operation can be identified. The instructions require the greatest care as to cleanliness, and sterilization of instruments used, and aseptic precautions at all stages. The apparent failure of so-called vaccination to protect against small-pox is really the failure of imperfect vaccination. The lessons taught by recent outbreaks are too clear to be ignored; they point to the necessity of thorough and careful vaccination in infancy (not less than four good marks or scars are essential for safety), and for revaccination between the ages of 13 and 16, to secure protection against small-pox. It is the sham and imperfect vaccination which gives a sense of false security, discredits the whole procedure, and acts as a source of danger to society. The experience of Sheffield in 1884, during an epidemic of small-pox, showed that the mortality of the vaccinated children was 31 times less than that of the unvaccinated, on the numbers attacked, and 670 times less on the respective classes living.

The following classified summary of 2361 cases of small-pox, treated in the Hospital Ships of the Metropolitan Asylums Board, tells the same tale of the value of vaccination if efficiently performed:—

Character of vaccination	Cases of small-pox.		Totals		
	Discrete.	Confluent	Cases.	Deaths	Percentage of deaths to cases
Under 10 years of age:					
Having scars of ½ sq. in. total area	21	0	21	0	–
,, ,, between ¼ and ½ sq. in. area	12	2	14	0	
,, ,, less than ¼ sq. in. area	19	0	19	0	
,, ,, unrecorded area . . .	2	0	2	0	–
Over 10 years of age					
Having scars of ½ sq. in. total area	794	30	824	17	2·06
,, ,, between ¼ and ½ sq. in. area	215	13	228	6	2·60
,, ,, less than ¼ sq. in. area .	345	21	366	12	3·20
,, ,, unrecorded area .	128	12	140	7	5·00
Total vaccinated { Under 10 years	54	2	56	0	–
Total vaccinated { Over 10 years	1482	76	1558	42	2·60
Evidence of vaccination inconclusive { Under 10 years .	10	9	19	6	31·50
Evidence of vaccination inconclusive { Over 10 years . .	173	58	231	38	16·00
No evidence of vaccination { Under 10 years .	217	65	282	63	22·30
No evidence of vaccination { Over 10 years . . .	140	75	215	31	14·40

The question naturally arises—What is efficient vaccination? To secure it the official instructions of the Local Government Board prescribe that public vaccinators shall "in all ordinary cases of primary vaccination make such insertions of lymph as will produce at least four separate good-sized vesicles or groups of vesicles, not less than half an inch from one another. The total area of vesiculation on the same day in the week following the vaccination should not be less than half a square inch." That there is abundant evidence of the correctness of this instruction, and of the need of its observance as a minimum of efficiency, has already been indicated.

There is every reason to hope that in the near future, the principles of this method of infectious-disease prevention may be extended and practically applied to the prevention of other diseases besides small-pox. That, for instance, it may be found possible to pass the contagion of scarlet fever through some one animal or another, just as small-pox is passed through the calf, so that when re-introduced by inoculation into the human subject, it should induce so little or mild disease as to protect the body against the more serious and true disease. What is known as Haffkine's method of protective inoculation against cholera and plague is an elaboration of this idea, and offers considerable encouragement to others to work upon similar lines in regard to other diseases.

As regards methods of treatment, the development of this principle is already showing encouraging results in the success which has followed the treatment of diphtheria by means of "antitoxin." This antitoxin is present in and is yielded by the serum from the blood of horses which have been repeatedly inoculated with the toxine of diphtheria. In a similar way, the efforts to obtain an antitoxic preventive against tetanus by means of the serum of the blood from horses, asses, and goats, previously inoculated with the toxine of tetanus, are full of promise.

The experiences of daily life show that epidemics or outbreaks of scarlet fever, measles, and other diseases of this kind, vary widely in their severity, sometimes being very fatal; at other times, though attacking large numbers, yet causing few deaths. The thought naturally arises whether, in these milder outbreaks, the intensity of the contagion or microbe has not been lowered by passing through a number of persons in succession, each of whom was only slightly susceptible to it. Similarly, in the case of the severer epidemics, whether the contagion has not gained intensity by passing through a succession of individuals, each of whom was exceptionally favourable to its development. These are some of the ideas and problems which at present are troubling those whose aim it is to keep infectious disease in check; their

ultimate development and solution are probably but a question of time; but pending this, attention needs to be closely directed to the modes by which infection generally is given off from the sick, and to the means best adapted for its destruction.

Means of Infection.—From what has already been explained, it will be clear that although the causes of certain diseases act within the body, they really arise from without, and gain access to the body by different ways or methods. The chief means of infection are by air, food or drink, and clothing, to which may be added, in the case of some of the less common diseases, inoculation and absorption by some mucous surface. As regards the reception of infection, it is well established that many diseases are conveyed through the air, and the infection inhaled by the act of breathing. This is the probable means of communication of such diseases as small-pox, chicken-pox, scarlet fever, typhus fever, measles, German measles, whooping-cough, mumps, diphtheria, and often tuberculosis, also of certain infectious forms of inflammation of the lungs.

It is not quite clear how far air receives its infectious qualities from the breath of persons infected with diseased throats, or by exhalations and the desquamated particles from the skin, as in typhus, small-pox, and in scarlet fever. In any case, infection through the air presupposes the existence of microbes, or their spores, in a more or less dry state, floating about as impalpable dust; conditions which we know are not inconsistent with their vitality. Little is known as to the precise distance to which infection can be carried through and by the air. Experience goes to show that scarlet fever and typhus can only infect at short distances; that whooping-cough and measles can do so at greater; while the occurrence of a radiation of infection round certain small-pox hospitals, indicates the possibility of small-pox infection at long ranges, the number of cases infected therefrom diminishing as the distance from the hospital increases. It is necessary, however, while attaching importance to these hospital experiences, not to overlook the possibility that some of the cases may be spread by personal intercourse, particularly as it is difficult to secure absolute perfection in the regulations controlling the access of tradesmen, friends of the sick, and others, to the building. Food and drink, especially water and milk, are known to convey the poison of enteric fever, cholera, diphtheria, tuberculosis, and even scarlet fever; the germs being in such cases swallowed. Carelessness, and want of cleanliness of the hands, have been the cause of carrying infective matter to the mouth, notably in the case of those tending upon the sick; while clothing is a most notorious aid and means for the harbouring, preserving, and conveyance of microbes,

germs, contagia, and the like. A few diseases, such as glanders, anthrax, erysipelas, and some of the parasitic skin diseases, are more often than not transmitted by either direct contact, or inoculation. In no case can any hard-and-fast rule be laid down as to the precise mode by which any particular infectious disease is communicated to another; whether by means of air, food, drink, personal contact, inoculation, or clothing. Many of these affections are transmitted by one or more of these ways. Inoculation and absorption are the rarer means of infection; but are very generally associated with the occurrence of such diseases as hydrophobia, glanders, and anthrax, which are distinctive as being common to both men and animals.

Anthrax, or malignant pustule, is a very fatal disease, often given to man from animals, either by means of hair and wool, or from clothing. It is sometimes called woolsorters' disease, owing to its occasional prevalence among men employed in sorting various foreign wools. The infecting agents are the spores of a bacillus. When the spores are ripe, they may either take on a resting stage, or under favourable circumstances, commence germination, like a seed. The spores may infect a farm for many months: indeed, Delepine has shown that in this way most of the outbreaks of anthrax can be explained, the infection clinging to the land for very long periods. The chief channels of infection are (1) by the alimentary canal; (2) through the skin; (3) by the respiratory tract. Although alimentary infection is rare in man, it is the usual mode of infection in animals, due to their grazing on infected pasture land. Infected water, as well as fodder, may convey the disease. Cutaneous anthrax, when it occurs in man, goes by the name of malignant pustule, and is caused by infective anthrax matter gaining entrance through abrasions or ulcers in the skin. It is most common among those whose occupation leads them to handle hides or other anthrax material. From the local sore or pustule, a general infection may result, and when a fatal issue occurs, it is due to the absorption of toxins. Accidental infection with anthrax has been held to be an accident to employees under the Workman's Compensation Act, 1897. Infection through the lungs is perhaps the commonest form in man, and well known under the term "woolsorters' disease," or pulmonary anthrax. This mode of infection occurs when dried spores are inhaled in processes of skin-cleaning.

To avoid the dangers attending the sorting of the more commonly infected wools, it is necessary and usual to wash and disinfect them, also to insist upon careful washing of the hands by all workmen before eating, and to change their clothes before going home. The actual sorting-rooms should be well ventilated,

and artificial arrangements made for carrying away the dust while the bales are being opened.

Where cattle are infected and die, the carcasses should not be opened and exposed to the air. The chief source of danger is the infection by anthrax blood or discharges (containing spore-bearing bacilli) of the fields, farmyard, byres, etc. In these cases it is necessary for thorough disinfection to be carried out, if infection has occurred. When possible, the entire carcass of an infected animal should be burned; failing this, it should be buried deeply with lime above and below it, and, if possible, the place of sepulture railed off for a term of years to prevent other animals grazing over the spot.

Chicken-pox.—This, though usually a very mild disease, is, without doubt, infectious. The eruption appears without any previous sickness, commencing on any part of the body, and is added to irregularly by fresh crops of vesicles for four or five days. As in small-pox, the length of the period of its infectivity depends upon the falling off of the scabs or crusts. Assuming that the incubation period of chicken-pox is a fortnight, a detention under observation or quarantine for eighteen days should be insisted upon in the case of all children after exposure to infection by this disease before they return to school or mix with their fellows. Owing to the difficulties often associated with the correct diagnosis between chicken-pox and small-pox, it is very desirable that the former affection should be scheduled as a notifiable infectious disease, to minimize the risks of cases of the severer disease being overlooked as being those of the milder one.

Cholera.—It is usual to speak of this disease as being endemic in that part of India known as Lower Bengal, because it is constantly present in that district, but there is reason to believe that its endemic area is not, strictly speaking, limited only to that part of India, but that it is endemic in several countries of Central Asia. From these endemic areas cholera has at one time or other extended widely over the earth's surface, reaching on more than one occasion even these islands. The mortality from this disease is enormous: in 1866, which was the last occasion on which cholera was epidemic in England, the mortality was 672 per million of people; in 1892, when the disease was epidemic in Russia and Hamburg, the mortality was 45 per cent. of those attacked. Warmth of climate seems to favour the activity of the cholera poison, inasmuch as it usually attains its greatest prevalence during the months of June, July, and August. Excessive wet or cold arrests the disease, but moderate rainfall seems to favour it. Although all races seem to be liable to attack, the negro race appear particularly to be so. It is now universally acknowledged

that the infective agent of cholera is a micro-organism, called from its characteristic shape the comma bacillus; and that this exists in and is given off by the sick person in enormous numbers in the intestinal discharges which are so typical of this disease. In its mode of spread, cholera closely resembles enteric fever and epidemic diarrhœa. In all these diseases, contact with the sick is comparatively free from danger, the infection being given off by the bowel, and contained in the stools or evacuations, and in clothing or water fouled by them. Practically in only a very few cases is the infection carried by the air, and then only a limited distance; the vast majority of cholera cases are due to infection following human intercourse—that is, where the cholera-sick man goes, there with him goes the cholera infection. How far he will be able to diffuse the disease around him to others "depends entirely upon the filth facilities which exist; these facilities being those for fouling the soil, water, and air. It is a filth-sodden earth, an excrement-reeking atmosphere, and sewage-tainted water which are the true causes of cholera." These conditions all exist largely in Asiatic towns and villages; and just so much as these same conditions exist among European communities will cholera proportionately prevail.

The influence which animal pollution of the soil exerts upon cholera causation and prevalence has been largely dwelt upon by Pettenkofer and others, who in some places have traced a direct relation between movements of the subsoil water in polluted soil areas. The essence of this idea is, that the soil having become, at some time or other, fouled by the discharges from the cholera sick, contains in itself the infective agent of the disease. Any fall in the ground-water leaves the soil above it moist and full of air; these circumstances, if combined with a certain degree of soil warmth, are conditions favourable to the activity and vitality of the cholera organism, which eventually becomes dislodged from the soil by ascending air-currents. Any rise in the ground-water level would, of course, have a reverse or fixation effect upon the soil-contained micro-organism. It is difficult to readily understand any frequent occurrence of this train of events, still the origin of many outbreaks of cholera in which no history of imported infection can be traced, is only to be explained by some such diffusion of an unexhausted specific contamination of the soil in previous years. From what follows, it will be seen that, especially in regard to its connection with soil conditions and emanations. cholera bears some resemblance to epidemic diarrhœa, and that, in both cases, in localities in which the diseases are endemic, the soil is so charged with the necessary infective organism that direct emanations from it disseminate the

disease. This soil origin of cholera is probably true for outbreaks in the endemic Indian area, but not so for outbreaks in England and Europe, where contaminations of water supplies and the like constitute the chief and only means of dissemination.

The preventive measures to be adopted are isolation, disinfection of all clothing and excretal discharges, combined with the investigation and correction of all sanitary conditions which are conducive to outbreaks of the disease. A matter of considerable importance in this direction is the due appreciation of the fact that the infectivity of cholera evacuations last longer often than the existence of acute symptoms. The want of a proper recognition of this fact probably has been the cause of very considerable diffusion of infection in the past. The only safe precaution is to continue destroying by fire, or adequately disinfecting all bowel discharges for at least ten days after convalescence has commenced. This remark is equally applicable to both diarrhœa and enteric fever as it is to cholera.

Epidemic Diarrhœa.—This is essentially a disease of towns and crowded areas, its incidence being greatest upon young children below two years of age. Outbursts of epidemic diarrhœa occur nearly every year, the most usual season being in the months of July and August. The chief facts concerning the prevalence of this form of disease may be summarized in the terms of the results of Ballard's inquiry into its causation as explained in his Report to the Local Government Board in 1887.

"That the essential cause of epidemic diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism not yet isolated."

"That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum."

"That occasionally such organism is capable of getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material (especially food, whether inside or outside the body), which serves as a nidus and pabulum."

"That from food and from organic matter in certain soils it can manufacture a virulent chemical poison which is the material cause of epidemic diarrhœa."

A variety of micro-organisms have, from time to time, been alleged to be the causal agents of this disease, but the evidence so far does not warrant our dogmatizing on the point. The most

we can say is that the epidemic diarrhœa of this country is apparently, in the great majority of cases, the result of the infection of food by bacteria belonging to the colon group, and which are present usually in fæcal matter. It is probable that this infection of food with intestinal bacilli does not lead generally to serious consequences unless the infection be gross from the first, or the food be kept long enough and under conditions of temperature favouring the multiplication of the micro-organism. The infection of milk at the farm, during transit, or by faulty storage in the home, is perhaps the most common cause of epidemic diarrhœa; but other foodstuffs are equally liable to infection, especially where carelessness prevails as to cleanly and wholesome storage. It is notorious that towns which have adopted the water-carriage system of sewerage have, as a rule, much less diarrhœa than those retaining other methods of excretal removal. Further, towns with the most perfect scavenging arrangements, particularly the removal of house-refuse, have the least epidemic diarrhœa. These facts have suggested that the disease is due to surface pollution derived from street-dust, particularly dried horse-manure. Ballard's inquiries clearly indicate the influence of soil to be decided, and that communities living upon loose soils suffer more from this affection than those where the dwelling-houses have as their foundation solid rock, with little or no superincumbent loose material. Summing up the position, we may say that epidemic diarrhœa is a bacterial disease, its occurrence depending wholly or partly upon surrounding temperature, deficiency of rainfall, surface-dust, and consequent pollution of food, chiefly milk. The exact relationship which these conditions have to each other is not known.

As already stated, diarrhœa, particularly in its epidemic form, is very fatal to infants, among whom it produces a mortality of about 25 per 1000 of births. The mortality lessens from infancy to 20 years of age, after which it increases again, being particularly fatal in extreme old age. Certain towns, notably Preston and Leicester, enjoy an unenviable notoriety for their very heavy mortality from epidemic diarrhœa every year. Most other large towns suffer in the same way each summer, but in a less degree.

A distinction must be made between the epidemic diarrhœa indicated in the foregoing and certain epidemic outbreaks of diarrhœa which occasionally occur in public institutions. These latter can usually, upon investigation, be traced to articles of food or drink, especially water, when containing excess of mineral salts, sewage, or vegetable matter. Similarly, milk and butter, or cheese, may give rise to diarrhœa, owing either to fermentative changes in themselves or to fouling by some specific gas. Tinned

meats, pork pies, ham and game, or even fish, have on several occasions been traced as the ultimate cause of extensive diarrhœal outbreaks. In these cases, the poison partakes of the nature of a chemical body, the product of putrefactive changes in the food-stuff, and is altogether unassociated with the climatic conditions hitherto considered.

Diphtheria.—This is another disease largely diffused by the air, more particularly at short distances; the reason being that the microbes of the affection swarm in the exudations and secretions of the nose, mouth, or throat, and infection readily follows the inhaling, swallowing, inoculation, or absorption of any of them. The vitality of the micro-organisms of this disease is great—so much so, that they can survive long periods of time when attached to, or hidden away in, clothing. There is reason to believe that much of the spreading of this affection is due to the crowding together of susceptible persons, such as children in schools where the inadvertent presence of a single unrecognized case in its earliest stage is sufficient to infect, by means of the breath, many others. Besides an influence due to general dampness of the soil, there is a considerable amount of evidence in favour of the view that special and continuous dampness of the dwelling-house materially aids the production of diphtheria. One of the most striking facts in connection with outbreaks of this disease is, that they are so frequently preceded by a more or less widespread prevalence of cases of sore throat, varying much in severity. So often have outbreaks of true and typical diphtheria, following minor throat illness, occurred in particularly isolated places and under conditions which exclude the likelihood of their having resulted from any importation of the infection from elsewhere, that an idea has grown that possibly ordinary sore throats may be able to acquire a progressive degree of the property of infectiveness. At present there is no precise knowledge as to the fact of this actually taking place; but it is suggestive of the need to correct any faulty sanitary conditions of schools and other buildings which may in any way tend to ill health. In connection with the sudden appearance of diphtheria in isolated localities, the question of conveyance by the air or otherwise arises. The experience of the behaviour of diphtheria in houses and hospitals shows that its infection is readily conveyed through the air of rooms for short distances, and to those in close actual contact with the sick; but there is little evidence in favour of the view that the diphtheria contagion can travel very far and yet retain its virulency. It is much more probable that the infection can be, and is, transmitted from place to place by adhering to clothing and persons, or even to animals

and food. The facts connected with more than one outbreak of diphtheria among children and adults have shown the existence of a concurrent throat disease among domestic animals and birds, more particularly cats, sheep, horses, cows, fowls, turkeys, and pigeons. The investigations of Klein, reported to the Local Government Board, indicate that cats have diphtheria, and that cows can suffer from an ailment so slight in appearance as to be unnoticed by the dairymen, but capable of imparting infective qualities to the milk which give rise to diphtheria among those consuming it. Hence, another reason for boiling milk before use.

For many years it was thought that accumulations of filth and drainage defects were the direct cause of the origin and spread of diphtheria. In the light of more recently acquired knowledge, there is reason to think that this older belief must be modified, and that the true part which insanitary states play, is by way of predisposing to infection by lowering the standard of health rather than by being the actual origin of the disease. As in the case of scarlet fever, there is no evidence that diphtheria is spread by the agency of drinking-water. Some have said that the diphtheria germ can find a resting-place, in which it can long survive, in the surface soil, and that a rise in the subsoil-water, by expelling the ground-air, leads also to the expulsion of the micro-organisms, and so originates some of the outbreaks of this disease. At present there is nothing definite known on this point, though a considerable number of facts have been collected which lend some support to this view of the relationship between the fluctuations of the ground-water with diphtheria prevalence.

Diphtheria outbreaks are noticeable for being associated frequently with cases of so-called "croup," and with a series of antecedent cases of scarlet fever. Some doubt has long existed as to the precise meaning of these associated cases; the true explanation probably is that what is called croup is oftener than not unrecognized diphtheria or, at least, a form of laryngitis. In the other association, it is probable that scarlet fever leads to more or less temporary damage to the mucous membrane of the throat, and in this manner predisposes to the reception of the diphtheria poison, causing a series of diphtheria cases to follow after a series of scarlet-fever cases. Both diseases appear to be more prevalent during the autumn and winter, than during the spring and summer. During 1903, the deaths from diphtheria in England and Wales were in the proportion of 195 to a million persons living.

Enteric Fever.—This disease is often called typhoid fever, and

by some Continental writers spoken of as abdominal typhus. It is frequently prevalent in this country, especially during the autumn months, its average annual death-rate per million living for the last five years having been 166. True enteric fever appears to be rare among infants and young children; it is most prevalent in youth and adolescence, the cases becoming fewer and fewer after the age of thirty. Judging by the average severity of attack, more females die from it than males, the figures being 19·7 per cent. of deaths for female cases, and 13·8 for male. As with many other infectious diseases, enteric fever appears to confer a protection against a second attack; its incubation period is long, and its course exceedingly variable. Enteric fever is closely associated with a micro-organism, and is essentially a communicable disease. It is now well established that the poison or infection of this disease is given off from the body of the sick person in association with the excretal discharges, and it is these which are so infectious. Formerly it was considered that the bowel discharges were the chief, if not the only, vehicle by which the infection passes from the body, but more recent investigations indicate that the urine also may serve as the medium for the diffusion of the infective agent. Air does not appear to carry the enteric-fever poison under ordinary conditions; though when clothing, bedding, and other objects have been soiled by the enteric discharges, and these have been allowed to dry and pulverize, there is no reason to doubt but what an active dissemination of the disease infection may result by aerial diffusion of dust particles. The most common means by which the infection of enteric fever finds its way into the body of another is by way of the alimentary canal, as for instance along with water or milk. Innumerable instances are on record in which direct and obvious excremental contamination of wells, springs, rivers, and cisterns has been followed by enteric-fever outbreaks. Perhaps one of the most remarkable and extensive of this kind of epidemic was that which prevailed in 1890–91, in the lower Tees valley, caused primarily by the wholesale fouling of the river at Barnard Castle, at a spot above the intake of the drinking water supplied to the neighbouring districts of Stockton, Darlington, and Middlesborough. Milk is another medium which has long been recognized as a means for the spread of enteric fever; the infection being sometimes traced to the use of polluted water for washing out the cans or diluting the milk, and in not a few cases to the milk being infected more or less directly by a person suffering from the disease. Just as there is supposed to be a bovine scarlet fever and diphtheria, so is it now believed by many that there is also a bovine enteric fever, the infection of which is

communicated by the milk yielded by the affected cows to those who consume it. It is questionable whether the popular idea of mere sewer gases and emanations from drains can be regarded as direct causes of enteric fever; they undoubtedly predispose to ill health, and in that way may indirectly influence its occurrence.

Some authorities have dwelt strongly upon the influence which pollution of the earth by specific matter has in originating enteric fever; and in connection with this have traced a connection between movements of the ground-water and the occurrence of enteric sickness and mortality. In places where the soil is porous, the ground-water high, and wells and cesspools both more or less adjacent, doubtless this connection between rise and fall of the subsoil-water with fall and rise of enteric prevalence may hold good, particularly as experiments made at Netley show that the enteric bacillus can survive in soil for quite two months, and, moreover, can be recovered therefrom at the end of that time.

Flies, too, are capable of conveying enteric infection. This is particularly liable to occur where enteric discharges are carelessly disposed of, as by superficial burial: military experience in tropical countries, where flies are excessively numerous, has shown this source of infection to be very real.

From this statement of the nature of the infection, cause, and spread of enteric fever, it will be readily understood that the risks of infection from the enteric sick to others is greatest in small and crowded homes, where careful nursing, scrupulous cleanliness as to attendants' hands, and soiled bedding or clothing cannot be secured. When such can be obtained, as in the large hospitals, the enteric sick can be treated side by side with other cases with apparently little risk to the latter; the chief precautions needed as preventive measures being disinfection of all clothing and articles which have been soiled by the sick, no matter how slightly, scrupulous cleanliness of the attendants' hands, and the exercise of the greatest care to disinfect all excretal discharges, including the urine, and so dispose of them as not in any way to contaminate sources of water, milk, or food.

Erysipelas.—This has been defined as a spreading inflammation of the skin, accompanied by fever. It is met with all over the world, but less frequently in the tropics than in more temperate climates. From facts collected by Longstaff, erysipelas has a mortality in inverse ratio to the rainfall, in this respect resembling scarlet fever; it affects all races alike, and is especially fatal among the very young. Formerly it was usual to regard erysipelas as occurring either through a wound or without. To a large extent this distinction has been replaced by the belief that every case is caused by the poison entering the system through a

wound, though this in some instances may be so insignificant as to be overlooked.

The actual cause of erysipelas is without doubt a micrococcus; it is certainly an infectious disease, but somewhat variable in its infectivity. It at times runs riot in hospitals, especially in surgical wards, the most important favouring circumstances being defective ventilation, overcrowding, want of cleanliness, and defective drainage arrangements. Some people seem to be more predisposed to erysipelas than others; among such are the intemperate, the badly fed, and those who have had it before. Our knowledge at present is small as to what are the precise connections between erysipelas and the various forms of blood-poisoning, more particularly that peculiar kind of blood-poisoning associated with lying-in women or those recently confined Evidence is strong that there is a relationship of some kind between erysipelas and child-bed fever, as shown by the familiar fact that women in labour attended by doctors or midwives who are suffering from erysipelas, or even have been in contact with erysipelas patients, commonly get blood-poisoning or child-bed fever. Similarly, nurses, midwives, and doctors who attend, or come into close contact with, women suffering from blood-poisoning, frequently themselves suffer from erysipelas; also the new-born children of mothers with child-bed fever die in large numbers of erysipelas. To a less degree, erysipelas has some obscure relationship to diphtheria prevalence.

Influenza.—The recent series of epidemic visitations of this disease in this country have made its chief characteristics familiar to most people. Although the original home of this affection is not known, our knowledge is sufficient to convince us that it is a disease which has periodically prevailed in various parts of the world since very early times; and also that a particular micro-organism stands in causal relation to it. Influenza is remarkably infectious even in quite the early stage. Our knowledge as to how this disease originates and spreads is small; but what we do know indicates that its progress is quite independent of season or weather; that man is the chief vehicle of its diffusion; and that its epidemic prevalence attains its height amongst crowded communities. The curious tendency of influenza to recur at intervals in the same locality is suggestive that the contagion or germ may be able to live or thrive for considerable periods outside the human body; but whether this is in the soil or in the bodies of domestic animals is unknown. That these latter creatures suffer during influenza epidemics from symptoms extremely like it is generally accepted. If similarly circumstanced, both males and females appear to suffer equally from influenza; its mortality is

greatest in the middle and later periods of life, and especially among those weakened by disease, or at all predisposed to bronchitis and pneumonia. Experience indicates that the ordinary preventive measures are of little or no avail.

Malaria.—This term should be reserved for the specific disease caused by the malarial parasite; and in that sense we use it here. Malaria is caused by a number of microscopical parasites which live and propagate themselves in the blood. These parasites are not bacteria or bacilli, but micro-organisms of a more complex nature, namely, protozoa, which are carried from infected persons to healthy ones by the agency of certain species of mosquitoes, notably by the genus termed *Anopheles*. Formerly, malaria was very common in this country, particularly in the fen and marshy districts, but as the land became better drained and less waterlogged, so the essential mosquito species disappeared, and with it the ague. Malaria is characterized by marked intermittency, hence it is usual to speak of it as occurring in three leading forms: (1) *quartan*, depending upon a parasite which takes seventy-two hours to pass through its cycle of development, and marked by fever every third day; (2) *benign or mild tertian*, in which the parasite takes forty-eight hours to complete its cycle; (3) *malignant infections*, in which the fever is of a severe and continuous type, and in which the parasites assume a special or crescentic form inside the blood corpuscles.

The parasites which have been found invariably associated with all forms of malaria belong to the genus *Hæmamœba* of the class *Sporozoa* amongst the protozoa. They pass through a definite cycle of development, which is completed in a period of time corresponding to the type of fever or disease. In its earliest and simplest form, the malarial parasite is a motile amœbula existing inside a red blood corpuscle. As the amœbula increases in size, the corpuscle becomes paler, and the parasite living at the expense of the hæmoglobin of the corpuscle gradually destroys the blood-cell and converts the hæmoglobin into specks of pigment. After the parasite has gained its mature size and form an increase and concentration of pigment occurs, followed by a splitting up into segments. This segmentation gives rise to what is known as the "rosette" form. In reality, these segments are new amœboid bodies, or *sporocytes*, which, by the rupture of the eaten-out corpuscle, become diffused into the blood. Many of these sporocytes pass into the spleen or are destroyed by phagocytes or other cells of the body, but, in a few hours, many others reappear in the blood, and inaugurate a fresh stage or infection of healthy blood corpuscles. This is brought about by the sporocytes attaching themselves to and penetrating healthy red

blood-cells and setting up a precisely similar series of changes. In this way the multiplication of the malarial parasite is carried on in the human host or body, and each paroxysm of ague or malaria is related to the evolution cycle of a generation of these parasites, the commencement of the paroxysm coinciding with the maturation of a parasitic generation. This human or endogenous or asexual cycle is known as the "cycle of Golgi," and shown in the accompanying scheme (Fig. 70, 1 to 8). In this way, the parasite is propagated indefinitely in the human host. The form and size of the parasite varies according to the type or variety of the disease; thus, in quartan malaria the invaded blood corpuscles do not become so decolourized or altered in shape as in other forms, neither is the parasite so motile or so delicate in structure as in the tertian varieties of the disease. The rosette form is distinctly daisy-headed in appearance, consisting of from six to fourteen round spores or elements. In the benign or mild tertian type, the parasite is usually actively motile, showing deeply stained spots, the pigment granules being finer than in the quartan parasite. The rosette body in this species is composed of from fifteen to twenty-five smooth oval spores. This type of parasite is probably the commonest form found in malaria, and is widely distributed over the world. In the malignant infections, the amœbulæ are much smaller than in the benign types, are very active in their movements, and often exist in enormous numbers. Segmentation or sporulation occurs only in the spleen or internal organs, hence the sporocytes are not found in the peripheral blood. The most distinctive feature of this type is the formation of "crescents" (gametocytes), and the attacking of a larger proportion of red blood-cells. The crescents do not, as a rule, appear in the blood until about a week from the onset of the fever, and are not a true stage in the ordinary life-cycle: they are uninfluenced by pyrexia, and may persist in man's blood for a long time.

So far, we have merely considered the life-history of the malarial parasite within the human body, and were this organism unable to escape from man and pass into an intermediate host to undergo further developmental changes, there would be no transmission of infection to man. We know now that the necessary intermediate host is the mosquito, and it is only by means of the mosquito that the malarial parasite escapes from the human body, undergoes the necessary developmental changes, and re-enters man's blood. The various changes which take place within the body of the mosquito constitute then the extra-corporeal stage of the life-history of the malarial parasite; further, inasmuch as man cannot contract malaria without being bitten by a mosquito,

nor a mosquito infect another mosquito, so the position may be stated briefly as being "no man no malaria, no mosquito no malaria."

When malarial blood is observed outside the body, certain flagellated forms may be seen. In the malignant infections, they

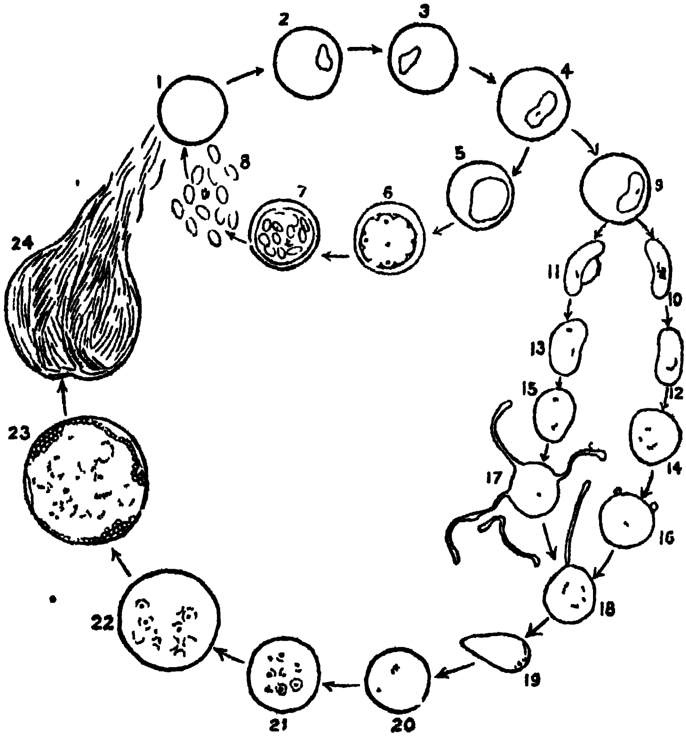


FIG 70 —Scheme showing human and mosquito cycles of the malaria parasite (after Manson) Nos 1 to 8 show the human or asexual cycle, Nos 9 to 24 show the mosquito or sexual cycle No 1 is a normal red blood cell, Nos 2 to 5 indicate red blood-cells containing an amœbula, Nos 6 to 8 represent sporocytes No 9 is a young gametocyte Nos 11, 13, 15 and 17 are male gametes or microgametocytes, Nos 10 12, 14, and 16 are female gametes or macrogametocytes, No 18 is a female gamete being impregnated by microgametes, No 19 is a travelling vermicule, No 20 is a young zygote, Nos 21 and 22 are zygotomeres, No 23 is a blastophore, and No 24 is a mature zygote

appear to be derived from the crescents (gametocytes), and in the quartan and benign tertian types of fever from the free spores of the parasite. This striking transformation is a stage of great importance, and indicates a vital evolutionary change or first stage in the life-history of the malarial parasite outside the human

body. Just as the segmentation body splits eventually into spores for the further propagation of the parasite in the blood of the malarial patient, so this flagellated body represents a provision for the propagation of the parasite in some living host outside the human body. The living host is the mosquito, and the chain of events may be stated thus. The gametocytes, which in some types of malaria assume a crescentic form, while in others they resemble the mature sporocytes, continue to circulate in man's blood for a while, or until they are transferred to the stomach of a particular species of mosquito. When so transferred, they escape from the enclosing red blood-cell, and can then be recognized as being of two kinds, the hyaline and the granular (gametocytes). The hyaline or male gametocyte emits a number of flagellated bodies (microgametes), which seek out and penetrate the granular or female gametocytes. The fertilized female gametocyte, now called a zygote, acquires locomotory powers, and as a travelling vermicule passes into the muscular wall of the middle intestine of the mosquito. It now grows rapidly, divides into a number of zygotomeres, which become blastophores filled with filiform spore-cells (sporozoits, zygotoblasts, or germinal rods). Ultimately, the zygote becomes encysted and packed full of zygotoblasts. When fully developed, say, twelve days after the mosquito sucked the malarial blood, it bursts and discharges the zygotoblasts, which are reproductive elements or spores. These pass into the insect's large veneno-salivary gland, whence they are emitted into the blood of the subject next bitten. These zygotoblasts are the actual infecting agents of man, and passing in this way from the mosquito into human blood, at once attack the red blood corpuscles, thus commencing the intra-corporeal or human phase already described. The mosquito phase occupies a period varying from six to sixteen days, according to temperature (Fig. 70, 9 to 24).

Up to the present time human malarial parasites have only been found in species of mosquito belonging to the genus *Anopheles*. The commonest species of mosquito is the *Culex* of the genus *Culicidæ*. The larvæ of the Culex mosquitoes live almost everywhere in warm countries, inhabiting any pot, tub, or cistern. In the fully developed insect, the palpi are short, proboscis thin, thorax large, and the wings unspotted. The larvæ prefer to lie in artificial collections of water, and are provided with breathing tubes (Fig. 71 B). The insect when resting on a wall carries its body parallel to the wall (Fig. 72 B). The host of the malarial parasite or *Anopheles* mosquito differs in various essential features from the *Culex* varieties. In *Anopheles*, the palpi are long, proboscis thick and long, body slim, and the wings dappled with dark spots

on their anterior margin. When at rest on a wall, the axis of its body is almost at right angles to the wall. Its larvæ have no

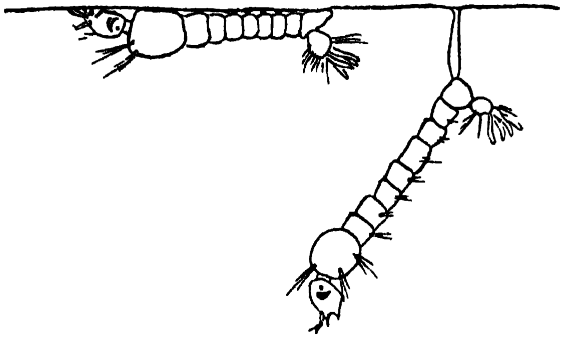


FIG. 71.—Larvæ of anopheles and culex mosquitoes lying on surface of water.

breathing tubes, consequently lie horizontally in the water of puddles (Fig. 71 A), looking like bits of thorns floating on the surface. While the *Culicidæ* are pot-breeding mosquitoes, the *Anopheles* are puddle-breeding. As is well known, it is the female insect which is the blood-sucker. After filling herself with blood, she retires to some dark sheltered spot near water: in a few days' time she deposits her eggs (300 on an average) in a mass or raft on the surface of the water. Within twenty hours or so, the eggs give rise to the tiny swimming larvæ; these grow, shed their skin, and become nymphæ or pupæ. From the nympha the young mosquito emerges. The entire cycle from egg to egg is about fifty days.

A B

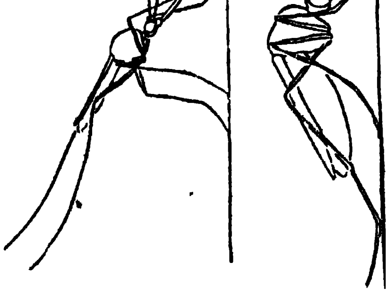


FIG. 72.—Anopheles and culex mosquitoes at rest.

Recognizing that the malarial parasite gains access to the human subject by means of mosquito bites only, the means of prevention must be directed mainly against the mosquito, or (1) prevention of mosquito breeding, (2) destruction of mosquitoes, (3) avoidance

of being bitten by mosquitoes, (4) the use of quinine, (5) isolation of the infected.

Measles, Whooping-cough, and Mumps.—These diseases have their infective germ contained almost exclusively in the mucus of the nose, mouth, and throat, or in the breath. They are all apparently very infectious, even in the earliest stages, the contagion or germ being capable of spreading, not only by the air, but by clothing, such as handkerchiefs, pillows, and bed-linen. What is known as German measles is a malady seemingly different from scarlet fever and measles, but having some of the characters of both. It is regarded as an entirely distinct disease, inasmuch as it occurs in epidemics, is able to protect against itself, but not against either scarlet fever or measles; nor do attacks of either of these diseases protect against it. Like measles and whooping-cough, German measles is contagious even before the rash comes out; fortunately, it has little or no mortality, and its power of infection is less active and less persistent than those of either measles or scarlet fever. Owing to their early infectiveness, all these diseases spread largely by the attendance of children at schools and other places of public gathering, who are merely sickening for them, and have not so far manifested the characteristic symptoms. There is no evidence that these diseases are ever disseminated by the agency of water, milk, or even by domestic animals. The mortality from measles in England and Wales during 1903 was equal to a rate of 291 per million children under five years of age living; for the same period, the rate for whooping-cough was 243 per million.

Rabies, or hydrophobia, has been already explained as being invariably caused by inoculation with the saliva of mad animals, mostly from bites by dogs, wolves, and even cats.

Relapsing Fever.—This is sometimes called "famine fever," and is very closely related to typhus fever. Climate and weather have no direct influence on this disease. Its chief causes are overcrowding and want of food. It is very infectious, being carried short distances by air, and also by means of clothing. A peculiar wavy micro-organism, called a *spirillum*, has been found in the blood of the sick, and inoculation of the same has been found to reproduce the disease in men and monkeys. Relapsing fever appears to afford but little protection against subsequent attacks, but does seem to have some protective action against typhus.

Scarlet Fever.—In this disease the infection reaches the air in the early stages, even before the rash appears, chiefly by the breath and mucous secretions of the nose, mouth, and throat. Later on, it is given off by the skin as well as by the breath, particularly in the form of fine bran-like scales of skin. Fortunately,

these do not appear to spread infection any great distance through the air; but, on the other hand, they lend themselves so readily to attachment to clothing that infection is retained for months, long after the original case existed. On this account, too great care cannot be exercised in burning, or, at least, adequately disinfecting, by some means or other, to be presently described, all handkerchiefs soiled by the nose and throat secretions, as well as all bedding and clothing which has been exposed to infection by the sick person. Until recently the above means of dissemination, namely, by immediate infection from a human case or indirectly by means of clothing, was regarded as the only possible method for the spread of scarlet fever. The remarkable inquiries made by the Local Government Board in a series of epidemics of this disease associated with certain dairies and milk supplies, combined with the results of Klein's investigation thereon, have, however, shown beyond doubt that human scarlet fever may be produced and spread by milk, which owes its infective property to a disease of the cow, and quite independently of any possible infection from a human source; though, in the majority of such milk epidemics of scarlet fever, the infection of a particular milk supply is from human scarlatina. These facts constitute a good reason why milk should be boiled before use. There is no evidence of scarlet-fever infection being conveyed by water, nor of its being carried any great distance by air-currents. In 1903 the deaths from scarlet fever in England and Wales were equal to a rate of 125 per million of the population.

Simple Continued Fever.—A disease under this name is scheduled in the Infectious Diseases Notification Act of 1889 as one to be duly notified to the sanitary officials. It is doubtful whether any separate disease of this name really exists. The term is usually applied to cases of more or less transient fever, unattended by any definite and constant symptoms other than those commonly associated with a high body heat. Careful inquiry generally throws light upon the cause of these cases, a great number of them in reality being but mild and irregular examples of more serious diseases, such as enteric fever, typhus, or even measles; hence the great practical value of duly giving notice of their existence.

Small-pox is infectious from the very commencement of the disease, the infection gaining intensity as the eruption advances, even up to and including the scabbing stage. The microbes or germs of the disease are contained in the secretions of the nose, mouth, and air-passages, as well as in the contents of the pustules or pocks. They are given off most freely, when these latter dry and scab, diffusing themselves to great distances in the form of a

fine dust. Owing to the great resisting power or vitality of these microbes, the spread of small-pox by means of infected clothing is even greater than that of scarlet fever. Individual protection against an attack of small-pox can be obtained in three ways: by natural small-pox, by inoculated small-pox, and by vaccination. In former years, protection once acquired was looked on as permanent and absolute; but later experience shows that from whatever cause obtained, the amount of protection varies according to the thoroughness of the protective procedure. Severe small-pox gives more lasting protection than mild small-pox; small-pox inoculation gives most protection when followed by an eruption; and a complete, thorough, and multiple vaccination gives more lasting protection than does a vaccination in which only a single small vesicle has been produced.

At the present time, a second attack of small-pox is less frequent than formerly, because as a result of the practice of vaccination, a first attack of the disease usually comes later in life, so that the protection it affords does not wear off in time to readily allow of a second attack.

Protection from small-pox by deliberate inoculation of the disease, or variolation, as it was called, was very generally practised in this country during the eighteenth century, and until made illegal in 1840. The chief objections to it were the danger to life which attended it, the disfigurement which so generally followed, and the fact that the inoculated went about spreading the disease broadcast. The researches and observations of Edward Jenner, between 1768 and 1798, led to the introduction of vaccination, or the inoculation of man with the small-pox of the cow, by which man contracted the affection called *vaccinia*. This vaccinia is, as Jenner always supposed it, small-pox of the cow; but owing to the remarkable change in the cow or calf of small-pox into vaccinia, the poison of human or ordinary small-pox is so weakened as to be unable to cause, except in rare cases, a general eruption or to spread by atmospheric convection; in fact, to use the words of McVail, the change in the calf from small-pox to vaccinia has the effect of "removing the objectionable and retaining only the valuable part of the original disease." Following the introduction of vaccination, there has resulted a remarkable decline in the prevalence of small-pox, not only in England, but in various European countries. This decline, it has been urged, was due, not so much to the use of vaccination, as to the decrease of inoculation and to increased attention to sanitation. That the mere decline in the practice of variolation was not the cause of a diminished small-pox prevalence is well shown by the experience of Sweden and Copenhagen, where it so happened that inoculation

for small-pox was never largely practised; yet the death-rate from small-pox per million of population was in Sweden, in the last century, no less than 2050, and now since the introduction of vaccination the death-rate is but 158 per million; the corresponding figures for Copenhagen are 3128 and 286. As bearing on the question of the influence of sanitation as a factor in the decline of small-pox, it has been pointed out by various writers, principally by McVail, that the statistics of all diseases teach that in reference to sanitation each disease has to be considered by itself. Though the removal of fæcal impurities has diminished enteric fever, it has not affected measles. The lessening of overcrowding and personal filth has much lowered the typhus-fever rate, but without reducing the diarrhœa rate. Vaccination has diminished small-pox without similarly affecting whooping-cough, and while general cleanliness and purity of water and food are useful against all diseases, yet "the lessening of small-pox cannot be set down to improved drainage any more than can the lessening of enteric fever be set down to vaccination."

The remarkable diminution in the small-pox death-rate since the introduction of vaccination is shown in the following table of small-pox deaths per million of people living in London:—

Years.	1660–1679.	1728–1757	1771–1780.	1801–1810	1831–1835	1838–1853.	1854–1871.	1872–1882.	1883–1892	1893–1900.
Death-rate per 1,000,000	4170	4260	5020	2040	830	513	388	262	73	41

During 1855–64, when vaccination was optional in Scotland, the annual death-rate from small-pox was 340 per million of inhabitants; but when vaccination was made compulsory the death-rate dropped to 80 per million for the years 1865–90. Edwardes gives some interesting figures from Sweden, where the small-pox statistics go back to 1774. From that date to the beginning of the nineteenth century the average annual death-rate was 2008 per million of people. From 1801 to 1815, vaccination was optional, and the death-rate fell to 631. In 1816, vaccination became compulsory in Sweden, and during the period 1816 to 1885 the death-rate has been 173 per million; while for the last eight years of that period it has been but 41 per million.

Perhaps the strongest argument in favour of the view that it is vaccination and not sanitation which has so reduced the prevalence and mortality of small-pox of late years, is the fact that in pre-vaccination times small-pox was very largely a disease of childhood, while now, owing to infantile vaccination, the main

incidence of the disease has been transferred to later periods of life. That this is the case is shown by the following table, taken from the First Report of the Vaccination Commission, p. 114, and which indicates the mean annual deaths from small-pox at successive life periods:—

Period	All ages.	0–5.	5–10	10–15.	15–25	25–45.	45 and upwards.
Vaccination optional, 1847-53	305	1617	337	94	109	66	22
Vaccination obligatory, but not efficiently enforced, 1854–71 . .	223	817	243	88	163	131	52
Vaccination obligatory, but more strictly enforced, 1872-87 . .	114	242	120	69		107	47

The same lesson is taught even more strikingly by noting that in the present day small-pox among the unvaccinated still selects its victims principally from the earlier ages; this is observable in statistics from all countries. No such change of age incidence is to be found in any of the other zymotic diseases, as is found to have taken place with respect to small-pox since the introduction of vaccination. As bearing upon the great protective power of vaccination during the early-age period, the following table, showing the statistics of some large towns, has been prepared by Dr. Bond, the Medical Officer of Health for Holborn: -

	Total number of cases of small-pox.	Children under ten years of age.					
		Vaccinated.			Unvaccinated.		
		Number.	Number of deaths.	Death-rate per cent.	Number	Number of deaths	Death-rate per cent.
London, 1891–1900	5,166	125	—	-	672	153	22·8
Leicester, 1892-3 .	357	2	- -	–	107	15	14·0
Sheffield, 1887–8 .	4,703	353	6	1·7	228	100	43·9
Dewsbury, 1891-2	1,029	44	1	2 2	174	56	32·1
Warrington, 1892-3	667	33	2	6·0	32	12	37·5
Gloucester, 1895–6	1,979	26	1	3·8	680	279	41·0
Manchester, 1892-3	805	11	—	—	36	7	19·4
Oldham, 1892–3 .	124	3	—	—	15	5	33·3
Leeds. 1892–3 . .	200	4	—	—	8	3	37·5
Halifax, 1892–3 .	330	4	—	—	38	15	39·5
Bradford, 1893 .	658	17	—	—	57	23	40·3
Totals . .	16,018	622	10	1·6	2047	668	32·6

Much valuable evidence has been collected of late years in regard to the duration of the protection which vaccination gives against small-pox. This evidence indicates that, although the susceptibility to the operation of vaccination returns comparatively soon after a primary vaccination, the susceptibility to small-pox returns but slowly; so slowly, in fact, that the power of infantile vaccination against attack by small-pox may be said to remain at least to one half of its original extent at twenty years of age. On these points the evidence given by Gayton before the Vaccination Commission in their Second Report, p. 245, is peculiarly interesting. He found that some 40 per cent. of vaccinated children could be revaccinated at the age of from six to ten years; but of vaccinated children of the same age exposed to the infection of small-pox by residence with cases of the disease, less than 10 per cent. were attacked, though under the same exposure no less than 92 per cent. of unvaccinated children of the same age contracted the disease. If we compare the attack rates under exposure with the fatality rates among attacked persons in successive age periods from birth upwards, as shown by the statistics of the great small-pox hospitals, we find that resistance to death by small-pox among the vaccinated outlasts very considerably resistance to attack by small-pox, and also that the inclination to both attack and death by small-pox is much slower in course and much less in ultimate amount in the well vaccinated than in the badly vaccinated.

The circumstances of a recent outbreak of small-pox among school children at Ossett, near Wakefield, furnish an interesting commentary on this question.

The undenominational school at Commonside, Ossett, is a public elementary school with a mixed and infants' department. The latter is practically separate, while the mixed department consists of three rooms under the same roof, in which the number of scholars was as follows: Room A, 69; Room B, 74; Room C, 26; total, 169 scholars.

On October 27, 1904, the schoolmaster observed a girl in Standard IV. with a suspicious rash on the hands and face. No time was lost in calling in the Medical Officer of Health, who promptly diagnosed small-pox, and caused the case to be removed to the hospital. Disinfection of the premises, vaccination of contacts, and all other precautionary measures were put in hand, but, as the subsequent events show, the infection had been sown already, bearing fruit according as it fell on good or bad ground. From the figures furnished by Dr. Kaye, the County Medical Officer for the West Riding of Yorkshire, we get the following instructive summary:—

Room or class.	Unvaccinated scholars. (a) Taking small-pox.	Unvaccinated scholars. (b) Escaping.	Vaccinated scholars. (a) Taking small-pox.	Vaccinated scholars. (b) Escaping.	Total scholars. (a) Taking small-pox.	Total scholars. (b) Escaping.
Room A:						
Standard IV., where first case occurred	8	0	0	19	8	19
Remainder of Room A . .	12	2	5	23	17	25
Room B	13	30	0	31	13	61
Room C	4	8	0	14	4	22
Totals	37	40	5	87	42	127
	77		92		169	

Such figures as these call for little comment. We have here the introduction of a case of small-pox into a class of children, some of whom were unvaccinated and the rest vaccinated. Every one of the former promptly took the disease, while all the vaccinated scholars escaped. In the rest of the school the conditions of this involuntary experiment were not so perfect; but even there the following facts stand out: (1) throughout the whole school not a single revaccinated person took the disease; (2) in the class originally infected and in rooms B and C every child who contracted small-pox was unvaccinated, although the vaccinated children predominated in numbers; (3) out of the 42 cases occurring in the entire school, only five had been vaccinated, and these five were in one class of older scholars, in whom naturally the effect of infantile vaccination was wearing off.

Some people profess to be much opposed to the practice of vaccination, and in support of this view allege that (1) vaccination neither prevents nor modifies small-pox; (2) that it gives rise to other diseases; (3) that it is unnecessary, as small-pox is only slightly infectious, and can be prevented by isolation in hospitals. No one who has studied the statistics, nor any one who has read the few facts explained above as to the real nature of the case, can for one moment honestly believe or think that vaccination neither prevents nor modifies small-pox. The truth is vaccination does both. With regard to the second contention, that vaccination gives rise to other diseases, much untruth has been both written and spoken by prejudiced persons. The facts appear to be that in a very small percentage of cases, certain diseased conditions have resulted either from or in consequence of vaccination having

been performed. But when these cases have been closely inquired into, it has been found that grave errors had been committed in the performance of the operation, and that due precautions had not been taken in the choice of the source of the vaccine lymph. Considering the enormous number of vaccinations that have been performed during the past fifty years, it is remarkable how few genuine cases have occurred in which disease has in any way resulted from the procedure. It is probable that with an increased use of vaccine direct from the calf, and the exercise of greater care even than has hitherto been exercised, the alleged risks of vaccination in this direction will quite disappear. Coming now to the third objection to vaccination, or the statement that it is needless because isolation is a better preventive than it, we find that on this particular allegation there is practically no evidence at all. What evidence there is, is based upon the experience of Leicester, in which town isolation of the small-pox sick has been very rigidly carried out. But this town is not an instance where isolation has been employed as a *substitute* for vaccination, because the great bulk of the inhabitants of Leicester have been vaccinated at some time or another, with the result that the experience of Leicester really only amounts to an experiment as to the efficacy of isolation, *plus* a certain amount of vaccination. Moreover, the doctors, nurses, and attendants of these isolated small-pox sick are all vaccinated individuals, which means simply that the patient has around him a cordon of protected or insusceptible people. Surrounded in this manner with persons protected from the disease, it is not remarkable that diffusion or communication of the infection has been small; but were the immediate attendants not thus protected by either vaccination or revaccination, it may be absolutely affirmed that isolation alone, as so understood, would rapidly result in an overwhelming increase in the numbers attacked with the disease.

Tetanus, or lockjaw, is essentially a soil or earth-poison disease, due to the presence of a bacillus. It is not infectious, but commonly occurs as the result of the inoculation or fouling of wounds by dirt, mud, or earth; this is the reason why it so frequently follows injuries to the hands and feet.

Tuberculosis.—This is a diseased condition which occurs in man in a variety of different forms, the most familiar being phthisis or consumption, scrofula, and meningitis. Tuberculosis is not limited to the human race; it is very common among oxen and cows as a disease known as "grapes," it also affects pigs as well as fowls, rabbits, and guinea-pigs. It is causally related to the action of a particular bacillus, and the existence of these bacilli in the expectoration of those afflicted with consumption

or tuberculosis of the lungs, suggests the communicability of this disease from one person to another, particularly by means of the air. That this is true in fact has been shown by the collection of numerous instances of the infection of whole groups of people, free from all hereditary taint, by mere residence in rooms or houses which had been previously occupied by persons suffering from tuberculosis. The infective microbes of consumption exist only in the expectoration, and are not given off by the breath of those suffering from this disease. This fact prevents their being spread through the air so long as the medium which contains them is moist; but once the expectoration becomes dry, then the germs are easily raised by draughts and scattered about as dust, in which form they gain access to the lungs. This sequence of events is very liable to occur when consumptive persons are allowed to spit upon floors or into handkerchiefs; but can be readily obviated by insisting upon all such affected persons spitting into spittoons which contain a little water, the contents afterwards being either burnt or buried.

Every one knows that tubercular disease is peculiarly liable to occur in different members of the same family, and this often through succeeding generations. These facts are not altogether to be explained as being a consequence of either direct or indirect infection; it is more probable that heredity is largely to be held responsible. In addition to direct infection by the inhalation of dust laden with the dried spores of the tubercle bacillus, and to the influence of inherited predisposition to the tuberculous infection, there are other causes which largely conduce to the prevalence of this disease. Among these are all unhygienic conditions of the dwelling or workshop; such as dampness, defective ventilation, overcrowding, and the inhalation of mechanically irritating dust-particles, as in the case of the various dusty trades.

Possibly of the first importance in regard to the spread of tuberculosis is the subject of its relation to food. This involves, not so much the question of how far deficient and indifferent food indirectly predisposes, like other insanitary circumstances, to tubercular infection, but how far food serves as an actual and possible carrier of the tubercular bacillus or germ. It has already been stated that cattle and other animals suffer from tuberculosis, and although the full identity of their sickness with that of the similar disease in man has not been absolutely settled, it has been sufficiently so demonstrated to indicate that the risks of infection through this source are grave. This infection may be either through meat, or by milk; and the evidence as to the possibility of either of these contingencies is sufficiently strong for us to condemn as unfit for food such parts of the carcase of a

dead animal in which signs of tubercle are manifest, and even condemn the whole carcase if the disease be far advanced and the beast emaciated. Possibly it would be wiser to condemn absolutely the whole carcase if there be evidence at all of tuberculosis in any part, no matter how limited in extent. There is ample experimental evidence to show that tubercle bacilli are present in the milk of tuberculous cows, and may even be present in the milk when the teats of such cows are unaffected with tubercle; further, that even when no bacilli are found in such a milk, the feeding of young and healthy animals with it gives rise in them to tuberculosis. The heat employed in cooking meat is insufficient to destroy the bacilli present in its deeper parts; but, fortunately, the danger of tubercular infection by milk is obviated by boiling, and this precaution, on this account, should be invariably adopted, especially when it is to be used for the feeding of children.

The view that tubercular infection can be transmitted to man by the ingestion of foodstuffs, especially milk and flesh coming from infected animals, has recently been called in question by Koch. Although his opinion has as yet received little acceptation, still Koch's researches into the nature of tuberculosis have been so thorough that any views which he may express on the subject have naturally considerable importance. The doubts raised by Koch involve an inquiry into at least two obscure points, namely, (1) is it possible that mixed infections may play some great part in determining an attack of tuberculosis? and (2) may there not be more than one variety of bovine tuberculosis, and may not the human tubercle bacilli be able to affect some breeds of cattle more than others? Setting aside these questions of whether bovine and human tuberculosis are the same, and whether they are mutually transmissible, it is still incumbent upon sanitarians to combat this infection through other channels than food. The more one looks into the subject, the clearer it is that the dissemination of tubercle infection is closely identified with indiscriminate expectoration and with the housing of the poor question. The necessity of educating people as to the infective character of tuberculosis and on the means by which it can be prevented, the need for notification, with a greater provision of open-air sanatoria, are all matters requiring immediate action if any real progress is to be made towards prevention. As to setting at rest any doubts or difficulties raised by Koch's recent utterances, we must await the final report of a Royal Commission on the subject which is now sitting. Until that report is made, there should be no relaxation in the taking of proper measures for dealing with milk from tuberculous cows, and with tuberculous meat which may be intended for the food of man.

Meanwhile they have thought it necessary to make an interim report, in which they express the opinion that tubercle of human origin can give rise in the bovine animal to tuberculosis identical with ordinary bovine tuberculosis. This statement clearly shows that it would be unwise to frame or modify legislative measures in accordance with the view that human and bovine tubercle bacilli are specifically different from each other, and that the disease caused by the one is a wholly different thing from the disease caused by the other.

The statistics published by the Registrar-General for England and Wales indicate that there has been a considerable diminution in the number of deaths attributed to tuberculosis, and that this diminution has shown itself in all forms of the disease except, perhaps, in general tuberculosis and tuberculosis of bones and joints. This improvement must be attributed in part to the betterment of the general sanitary conditions, and in part, perhaps, to the organized efforts which have been made in recent years to disseminate information as to the means which should be taken to prevent infection. In spite of all, tuberculosis is still too prevalent, for in 1902 it was the cause of rather more than one death in ten from all causes. It is more deadly in town than in country, as shown by the following corrected death-rates taken from the latest report available :—

	Average 1897–1901.	Year 1902.
England and Wales	1323	1233
Urban counties	1433	1322
Rural counties	1197	1136

It is a significant fact, illustrating the truth of the doctrine that an open-air life is the best prophylactic of phthisis, that, whereas the average phthisis rate among males was much greater in the urban than in the rural counties, among females—who, in country districts, spend so much more of their time indoors than men—the rate was nearly as high in the rural as in the urban counties.

The deaths from tuberculous meningitis are diminishing, but in 1902 still numbered nearly 6000 (5961). Of this total no fewer than 4056, or 68 per cent., were those of children under the age of five years. Very much the same story is to be told of tuberculous peritonitis; the total (5303) was much below the average for the previous ten years, but 3815, or 72 per cent. of the deaths, were those of children under five years of age. There

has also been a decrease in the number of deaths from tuberculosis of other organs and general tuberculosis, but, so far as can be judged, it has been less conspicuous. However this may be, the number is certainly large; 4048 deaths were attributed to general tuberculosis, over half the victims being children under the age of five years; the deaths from tuberculosis of bones and joints and other specified organs numbered 1413.

The importance of tuberculosis as a cause of death in childhood may perhaps best be gauged from the fact that the death-rate it produced among children under five years of age in the year 1902 was 3·06 per 1000 living, the death-rate from all causes being 49·07. In other words, of every 50 children who died, three at least died of tuberculous disease in one of its forms.

But the death-rate is very far from giving a true criterion of the prevalence of tuberculosis in childhood. Tuberculous disease of the glands, especially of the glands of the neck, is very common in childhood, causing much ill-health and leaving ugly scars, but not often ending in death. Tuberculous disease of bones and joints is also far more common in children than adults, and many of its victims survive permanently crippled.

In warring against tuberculosis it is again necessary to go back to the training colleges, and to impress upon future teachers the importance of understanding the predisposing and determining causes of consumption, so that they may know not only how to detect already existing cases, but what means should be taken in the school to remove the causes which predispose children to contract the disease.

Typhus Fever.—In former years, this disease was much more prevalent than now. It is very rarely met with in the present day, except in the poorest, dirtiest, and most overcrowded parts of towns. Its diminution is attributed to the removal of personal filth and overcrowding. The infection of typhus is largely communicated by air, though only at close quarters, being much weakened by air diffusion and dilution—that is, by ventilation. It occasionally is transmitted by means of clothing. It is only within comparatively recent years that typhus fever has been clearly distinguished from other fever, notably enteric fever and relapsing fever.

Yellow Fever.—This is a very infectious malady which frequently prevails in the West Indies, Mexico, Brazil, and on the West Coast of Africa. Spain and Portugal are practically the only European countries ever affected with it, and even there it rarely spreads. It is essentially a disease of towns, particularly sea-coast towns where insanitary conditions of every kind abound. Outbreaks frequently occur on board ship, and are even there

usually associated with similar filth conditions. The precise cause of the disease is believed to be a specific bacillus which clings to old badly ventilated ships and damp houses. Persons long resident in places where it prevails appear to have a remarkable immunity from yellow fever; new arrivals, on the other hand, are very readily affected. Its incubation period varies from one to five days; while its infectivity lasts some two to three weeks. There is at present no evidence that yellow fever is spread by infected water or milk, though probably in some cases it may be so diffused.

Recent researches by Sanarelli undoubtedly point to the disease having a bacillary origin, but there is much further work to be done before this can be precisely laid down. The endeavour to prove a man-to-man transference of yellow fever by means of gnats or mosquitoes has received much attention from a recent American Commission to Cuba. Some of their results are sufficiently positive to suggest that perhaps these insects play the same part in respect of this disease as they do in malaria, but before we can accept them absolutely, we need confirmation and fuller details concerning some of the facts. Their investigations certainly point to fomites playing a much smaller part in the dissemination of the disease than was formerly believed to be the case.

Their chief conclusions were as follows: (1) Bacteriological examination of the blood of persons with uncomplicated yellow fever during life, as well as of organs and blood immediately after death, is negative. (2) The mosquito known as *Stegomyia fasciata*, when allowed to suck the blood of a yellow-fever patient afterthe lapse of forty-one hours after the onset of the disease, and subsequently fed on sugar and water for twenty-two days, can, if permitted to bite a non-immune person, produce a severe attack of the disease. (3) *Stegomyia fasciata*, contaminated by sucking the blood of a yellow-fever patient, and then killed, cut into sections, and appropriately stained, presents with regularity a protozoan parasite, the *Myxo-coccidium stegomyiæ*, which can be traced through a cycle of developments from the gamete to the sporozoite. (4) *Stegomyia fasciata*, fed on the blood of a person with malarial fever, on normal blood, or artificially, does not harbour the myxo-coccidium.

Notification.—If, then, the foregoing is a true statement and explanation of the nature and causes of infectious diseases, what steps ought we and can we take on their occurrence, to prevent their extension to others? Expressed briefly, the special and only precautions we can take to prevent the spread of infection are notification, isolation, and disinfection.

By notification is meant the immediate intimation of the occurrence of every case of infectious disease to the medical officer of health. In the majority of places in this country, notification is by law compulsory on the part of the doctor attending the case, and by whoever is in charge of the patient; and on receipt of this intimation, the medical officer of health or sanitary officer has power to enforce such sanitary measures as may seem to him necessary. This law became necessary, and is likely to be necessary, because people, from a false sense of pride, are tempted to conceal the existence of infectious illness in their houses and families, with the result that the risk of spreading infection is not only greatly increased, but the chances of getting to know how and where it originated greatly impeded. If, on the other hand, one man or official is systematically informed of the existence of every infectious disease case, there is every chance of the cause of any outbreak being both discovered and removed, to say nothing of the greater security given to the community, that the health of the many will not be imperilled by the selfishness of the few. Under the Infectious Diseases Notification Act of 1889, the following diseases are scheduled: small-pox, cholera, diphtheria, membranous croup, erysipelas, typhus, scarlet fever, enteric fever, relapsing fever, continued fever, puerperal fever. Power is also given to the sanitary authorities, with the sanction of the Local Government Board, to include any other infectious disease, such as measles or whooping-cough. Valuable as it is, notification alone can never stamp out infectious disease, because, as already explained, many cases are so mild that they run their course, and give off infection to others without their true nature ever being suspected. This is especially the case during epidemics of diphtheria, scarlet fever, and small-pox, when persons suffer from sore throats, and attribute them to cold, or have an eruption and think it to be chicken-pox, with the effect that, taking no precautions, they unknowingly give the disease to others. For this reason, notification alone is inadequate to check the spread of infectious disease; it must be supplemented by both isolation and disinfection.

Isolation.—This, to be of the slightest use, needs to be thorough, and means that, when infectious disease occurs in a house, the patient or sick person must be completely separated from the rest of the household. This can usually be satisfactorily carried out in most private houses, but is almost impossible in small shops, workrooms, business premises, schools, or the crowded dwellings of the poor. In these latter circumstances, the only alternative is to remove the sick person to a fever or isolation hospital, where he will no longer be the source of danger to

others that he is in his own home. To relations and others, keen and anxious to nurse their own sick, the removal of them is often apparently hard and heartless, but a little reflection should convince them that it is equally heartless to expose others to the unsuspected risks of infection and death. On these grounds, the removal to isolation hospitals of the infectious sick, when so situated that their adequate isolation at home is impossible, is imperative in the interests of the community at large.

In all efforts to isolate a case of infectious disease in a private house, a room should be selected, if possible, on the topmost floor, and no other room be used on that level. The door of the room should, as far as practicable, be kept closed, or at least curtained off by means of a sheet kept saturated with some volatile disinfectant, such as a five-per-cent. solution of carbolic acid in water. The room itself should, if practicable, have a fire burning in it, and its windows kept open as much as possible. The room should be cleared of all unnecessary furniture, carpets taken away, hangings and curtains removed, and all stuffed or upholstered chairs replaced by plain wooden ones, such as can be readily cleaned. The passages and staircases leading to the infected room should be kept as airy as possible, by leaving windows open day and night, the idea being to so thoroughly dilute and ventilate the house that any chance escape of infection from the sick-room may be at once neutralized.

A special attendant or nurse should be detailed for the exclusive service of the sick person, and all general communication with the house reduced to an absolute minimum. Any articles brought to the room should be left at the door, or given to the nurse there, and no one allowed to enter except the nurse and the doctor. Those in attendance on the sick should not mix with the rest of the household, or, if this be unavoidable, the sick attendants or nurses should invariably remove their dresses in the sick-room, wash their hands and face, and then put on fresh dresses, kept either outside or in an adjoining room; an alternative arrangement is to wear a cotton overall or wrapper, which can be laid aside when leaving the sick-room. All crockery, such as cups, plates, knives, forks, etc., necessary for the sick person and the nurse must be kept exclusively for their use, and on no account allowed to mix with others, or be passed into and washed in the kitchen. The cleaning of these articles should be performed by the nurse, and be done either in the sick-room, or just outside. The dress of the nurse should be of linen; woollen and heavy stuff fabrics are inadmissible. The clothes worn by the patient, and all bed-clothes, should, as soon as removed from the person or bed, and, before being taken out of the room, be

soaked in a disinfecting solution, such as four fluid ounces of izal mixed with 1 gallon of water, and afterwards in every case be boiled and washed quite separately from the other household linen. The same care needs to be observed in the treatment of all discharges from the sick person. Thus all discharges from the nose and mouth, which, in cases of diphtheria, scarlet fever, and measles, are often both profuse and tenacious, should be wiped away with pieces of rag, which should at once be burnt; no handkerchiefs should be used; if they are, they must be burnt also. The bowel discharges so frequent in enteric fever, cholera, and diarrhœa should be received into bed-pans or utensils containing some disinfectant, such as corrosive sublimate solution (1 in 1000), carbolic acid (5 per cent.), or izal (5 per cent.), well stirred up, left for a quarter of an hour for the disinfectant to act, and either burnt, buried, or discharged down the closet; if the latter is done, it should be well flushed afterwards. In scarlet fever and small-pox, when the infective matter exists in the skin particles so freely given off, care should be taken to render these particles innocuous. With a little care, this can to a large extent be accomplished by washing the skin with warm water and carbolic soap, and then smearing the body surface night and morning with a medicated oleaginous preparation made by mixing one drachm of carbolic acid and three of eucalyptus oil in eight fluid ounces of olive or almond oil. In the same diseases, much good results by syringing or swabbing out with pledgets of cotton wool the mouth and nose, with a warm solution of common salt (about two drachms of salt with half a drachm of boric acid to a pint of water), and then burning the wool after use.

As concerns the length of time isolation should be maintained, we may say that it should be commenced so soon as the case is suspected to be infectious, and continued until the doctor says the sick person is safe to mix with others. It has already been explained that this period will vary. Thus enteric fever, diarrhœa, and cholera cases need to be isolated until the bowel discharges become natural; whooping-cough for quite two months; small-pox and scarlet fever until the skin ceases to give off branny scales or scabs—this is rarely in less time than six weeks; typhus, diphtheria, and measles need isolation usually for a month; while mumps and chicken-pox for about two weeks.

Disinfection.—Allusion has already been made to the use of disinfectants in the management of infectious diseases, especially as an essential procedure to guard against their spread. Possibly with reference to no single matter concerning sickness and infection is there a greater amount of ignorance and misunderstanding among the public than on that of disinfection and

disinfectants. The term "disinfection" means the destruction of the particular germ or micro-organism upon which any infection depends, and the expression "disinfectant" is applied to any substance which can so kill and destroy infection. Unfortunately, many people regard disinfection as meaning, not so much the killing and destroying of germs, as the removing, covering, and destroying of unpleasant smells, or, at most, the arresting and impeding of putrefaction and the growth of microbes. While the first is carried out by a *disinfectant*, the second depends on the action of a *deodorant*, and the third upon what is termed an *antiseptic*. A substance which is a deodorant or antiseptic is not necessarily a disinfectant, neither is a disinfectant of necessity a deodorant. As a rule, of itself a bad smell does no harm, but it is of importance as indicating the existence and the presence of microbes; the mere smell can usually be disguised, removed, or hidden by such deodorants as eau de Cologne, camphor, sanitas, or even tobacco smoke; but these would all be useless as means of removing or destroying the germs which are the cause of the bad-smelling gases. Similarly, commencing putrefaction is checked by an antiseptic like Condy's fluid, but this fluid cannot kill and destroy the living infective matter or germs of disease, and is, in consequence, in no sense a disinfectant.

In actual practice, disinfection proper is largely aided by the preliminary removal of infection by the scraping and stripping of paper from walls, the washing and sweeping of floors, to say nothing of air perflation, and the washing, beating, shaking, and exposure of clothes. These procedures, excellent in their way, are uncertain and incomplete; the destruction of germs, or true disinfection, is only attainable by either heat or chemical means. For articles of small value, the safest plan is to burn them, but when this cannot be done disinfection is best secured by exposing them to either dry or moist heat. Experiments have shown that the highly resisting spores of bacilli are destroyed by an exposure for four hours to hot air at a temperature of 284° F., while steam at 212° F. killed them in five minutes. Everyday experience of disinfection shows that infective matter, to be destroyed, is rarely freely get-at-able or freely exposed, but lies enclosed in clothes, pillows, or beds, which are extremely bad conductors of heat. Unless raised to a heat which injures the fabric, hot dry air is unable to penetrate into the centre of non-conducting materials like blankets, beds, etc., and is in consequence unable to raise their deeper or central parts to sufficiently high a heat to destroy any germs lodged there. The prevalent idea of disinfecting articles of clothing by an exposure to dry heat in an oven is most mischievous and unsound, because, without the risk of

injuring the materials or fabrics, no greater heat than 220° F. can be employed, and this temperature, unless maintained for something like eight to ten hours, is incapable of destroying infection. Hot air moistened with steam is somewhat better than hot dry air, but much inferior in both penetrating and germ-killing power to steam, either superheated or saturated. Steam rapidly penetrates into the interior of articles, where undergoing condensation it imparts its latent heat to them.

Saturated steam has its temperature the same as, or near to, that of the boiling-point of the liquid from which the steam is derived, so that the steam condenses on very little cooling. Superheated steam, on the other hand, is steam that has had its temperature raised above that of the boiling-point of the liquid from which the steam is produced, so that it must be cooled down through several degrees of temperature before it condenses. It is, in fact, dried steam, and acts like hot air, the heat passing by a process of conduction. The difference between these two forms of steam depends upon the quickness with which condensation takes place. The saturated steam condenses on very little cooling, and therefore penetrates rapidly into articles, whereas the superheated steam is not so penetrating because there is no immediate condensation. The power of saturated steam to penetrate into fabrics may be explained as follows:—Under ordinary pressure, when water boils the temperature is 212° F., and to convert this boiling water into steam a still greater heat is needed, although the temperature of steam itself is only 212° F. This extra heat has been absorbed and stored away by the steam, and is in a condition known as latent heat, with the result that when steam is condensed back into water by contact with any cold surface the latent heat is given up again. Suppose a blanket is being exposed to the action of saturated steam: the steam enters its interstices and is there condensed, giving off at the same time its latent heat, which assists in warming the blanket. Further, when steam condenses to water, it contracts and occupies a much smaller space (roughly $\frac{1}{1300}$) than that previously occupied. The result is that a vacuum is formed, and more steam rushes in to fill it, to undergo in its turn condensation and contraction. In this way every part of the blanket is attacked. The same, of course, applies to mattresses and other fabrics: in fact, all bulky, badly conducting articles are, in this way, penetrated thoroughly by the steam, more especially if it be from time to time let off and reapplied, or used in the form of current or moving steam, so as to displace the cold air remaining in the interstices of the article. Steam (the temperature of which under ordinary atmospheric pressure is 212° F.) may be superheated to 230° F., so

that it will not condense until its temperature drops below 212° F. Hence it is that superheated steam is not so penetrating, there being practically no condensation. Saturated steam, on the other hand, is only a degree or so hotter than the boiling-point of its liquid, and so condensation takes place rapidly, a vacuum forms, more steam rushes in, and so penetration of the articles is rapidly and efficiently effected.

As practically applied in the present-day disinfecting machines, steam may be saturated or superheated, and in either case in the form of current steam that is in motion or confined under pressure. A great advantage of current steam is that it favours penetration by driving air out of the machine and out of the interstices of the various articles and fabrics in it. A saturated steam disinfecting machine (working at a pressure of 10 lbs., and the steam having a temperature of 240° F.) appears to be the best in practice, whether from the point of view of expense, danger, or efficiency. Such a machine is the so-called "Equifex." It consists of a strong, thin elliptical chamber made of boiler plate, carefully lagged on the outer side to prevent loss of heat by radiation, and fitted at each end with a tight-fitting door. This chamber is fitted with a light frame on wheels, on which clothing, etc., can be suspended; it is run out of the door for this purpose. The frame being run in again, the door is closed and firmly fastened. Steam, generated from an outside boiler, is conducted into the interior of the chamber, and all the air therein carefully expelled: the articles within the chamber are kept exposed to this steam at a pressure of about 10 lbs. for about twenty minutes, the steam shut off. A blast of hot dry air is drawn through the chamber at the last, so as to ensure the thorough drying of the articles which have been exposed to the steam; after this they are withdrawn. The machine is fitted with gauges and thermometers, by which the temperature and pressure inside may be definitely and exactly told. No jacketing of the machine is necessary, as in the case of those working with superheated steam: experience shows that a uniform temperature can be obtained in all parts of the chamber, together with a rapid and complete penetration of all bedding, clothes, and other articles. Experiments show that a temperature of 240° F. can be readily obtained in seven to ten minutes in the centre of a blanket folded sixteen times by means of a machine working with saturated steam at a pressure of 10 lbs. to the square inch, over and above that of the atmosphere. Other experiments made with a hot-air machine failed to obtain, under similar conditions, a temperature higher than 190° F., and that only after nine hours' exposure. In fact, hot air penetrates very slowly, the heat passing by conduction, much as it does in the case of

superheated (dried) steam. Saturated steam, then, is the ideal disinfectant, giving, under a pressure of 10 lbs. to the square inch, a temperature of 240° F. (120° C.), which is sufficient, by a contact of twenty minutes, to kill all germs and their spores.

The employment of superheated steam is secured by one of two ways: (1) By a jacket around the disinfecting chamber, in which outer jacket steam is kept at about double the pressure and some 30° F. hotter than that within the inner chamber, whereby the latter steam is kept constantly dried or superheated; machines of the older Washington-Lyon patterns are representative of this type. (2) By generating steam from a saline liquid, whose boiling temperature under atmospheric pressure is about 225° F., or much in excess of that of ordinary water under natural pressure. This is the principle of Thresh's disinfecting stove. This latter apparatus is effective, employing steam in the current state, and presents the further advantage of being much less costly than some other machines.

A disinfector which marks an entirely new departure in the methods of raising steam for disinfecting purposes has recently been placed on the market under the name of the "Velox." A feature of this apparatus is that the furnace consists of a series of large Bunsen burners specially designed to consume paraffin supplied under pressure. By effectually regulating the supply to the burners, it is claimed that a gallon of paraffin will get up sufficient steam and complete an operation of disinfection from beginning to end. This steam generator is known as the "flash generator," but as the steam so generated is apt to be superheated, it is conducted to a drum, and brought into immediate contact with water. Here the superheated steam is cooled, and the water quickly brought to the boiling-point, and from this boiling water saturated steam is admitted to the chamber for disinfecting purposes. The apparatus works with either confined steam at a pressure of 15 lb., or with low-pressure current steam. Prior to the actual disinfection of articles, arrangements exist for the rapid heating of the cold walls of the chamber by passing live steam through coils of piping and sucking a current of hot air into the chamber from the casing of the steam generator, while the effectual extraction of air from the interior of the chamber and its contents is secured by a vacuum producer. The act of disinfection practically resolves itself into the following stages: (1) a preliminary vacuum, subsequent to heating the chamber; (2) exposure to steam at 15 lbs. pressure for fifteen minutes; (3) a second vacuum production; (4) a second exposure to steam at 15 lbs. pressure for fifteen minutes. The preliminary heating of the chamber and its contents so effectually prevents condensation that subsequent

drying is hardly necessary, but should it be desired, a repetition of the hot-air current and the passing of steam through the internal coil make certain that the disinfected goods come out of the chamber in a dry condition. It is claimed for these disinfectors, whether working with confined or current steam, that the generation of steam is much more rapid than with other types of machine, and that the working expenses are trifling when compared with those having coal-fed furnaces, while the attainment of disinfection is equally effectual. We have had no practical experience with this apparatus, but from facts put before us the claims of the makers appear to be good.

The use of steam for disinfection, either superheated or saturated, cannot be carried out in ordinary houses, but the majority of health authorities now have some form or other of steam disinfecting apparatus, and are prepared to remove, disinfect, and return clothing, bedding, etc., free of charge. In sending articles for disinfection, by either dry or moist (steam) heat, it must not be forgotten that heat has a certain effect upon the colour and texture of fabrics exposed to it. Thus leather is shrivelled up and spoilt by steam, while hot dry air makes leather dry and brittle. Cotton and silk are not injured by steam at all, but, unless carefully regulated, are damaged by dry heat. Flannels, blankets, and woollen goods suffer little by either dry or moist heat, beyond some loss in colour; dyes appear to suffer little by either process.

The great drawback to the use of dry heat is the variation in temperature at different parts of the disinfecting chamber; and its effects upon fabrics vary according as to whether they are placed on the floor, or near the sides, or hung in the central or upper parts. With the use of steam, this variability of heat is not met with. As we have every reason to believe that infection—that is, disease germs—cannot resist a temperature of 220° F., or even 212° F., if completely and thoroughly exposed to it for some length of time, it seems unnecessary in most cases to carry the heat to excess. Practical experience goes to show that an exposure to 220° F. for one hour, or 240° F. for half an hour, is sufficient to disinfect ordinary infected materials. In the case of bedding, the hair or feathers in mattresses or pillows must always be taken out and loosened, before exposing them to disinfection by heat.

In circumstances where no means exist for disinfecting bulky articles of clothing and bedding by these methods, they should, if possible, be destroyed by burning; failing that, they should be boiled, or at least be allowed to soak for twenty-four hours in some disinfecting liquid, such as one of the following: (*a*) Izal, 5 parts to 100 of water. (*b*) Chloride of lime, 2 ozs. to 1 gallon

of water. (*c*) Carbolic acid, 5 parts to 100 of water. (*d*) Bichloride of mercury, $\frac{1}{2}$ oz.; hydrochloric acid, 1 oz.; aniline blue, 5 grs., to 3 gallons of water.

Without doubt, bichloride of mercury is the most powerful disinfectant; it suffers, however, from the disability of being very poisonous, deleteriously affects metals, and forms insoluble compounds with organic matter. Stains are apt to be fixed by it. For these reasons, we think the practical utility of the bichloride of mercury as a general disinfectant is limited and inferior to carbolic acid, izal, cyllin, the various cresols, and other proprietary preparations of the higher phenols now in the market.

Many of the so-called disinfectants in common use are absolutely unreliable, particularly when unduly diluted. Large numbers of people appear to regard Condy's fluid as a disinfectant. It is merely a solution of the permanganate of soda or potash, which, as a powerful oxidizing agent, though capable of sweetening foul discharges from wounds, is nearly powerless to destroy the germs of infection. Clothes and bedding, therefore, which are merely dipped or soaked in it cannot be said to be disinfected Chloride of zinc, in the form of Burnett's fluid, is much more powerful. It is well adapted for disinfecting cholera and enteric discharges, but is less so than either carbolic acid or the bichloride of mercury. Sulphate of iron, or green copperas, if used in the strength of 1 lb. to a gallon of water, makes a valuable disinfectant for drains, but owing to its staining powers, is unsuited for soaking linen or clothing. Sanitas, chloralum, eucalyptus, camphor, thymol, boric acid, and iodoform are not true disinfectants, or only so in the weakest manner. They are unfitted for the disinfection of fabrics and clothing.

Fumigation.—All attempts to disinfect clothing, bedding, etc., by mere fumigation at home should be discouraged, as it rarely succeeds in destroying the germs of infection. Far too great importance is attached by people to fumigation, and to the influence of chemical vapours as purifiers and means of disinfecting the air. The truth is, aerial disinfection is more or less of a delusion unless the air be rendered unfit to breathe. We should not aim at purifying old or fouled air, but rather renew it by free dilution and ventilation. It is, even in these days, no uncommon thing to see people placing saucers of Condy's fluid or carbolic acid about sick-rooms, or spraying the air with vinegar, terebene, eucalyptus, and various other volatile agents, under the impression that they are disinfecting the air. All these efforts are in the main useless, and give a false sense of security, which at the same time diverts attention from more efficient measures. They, moreover, are based upon

a wrong principle; we cannot and do not need to disinfect the air of a given room or space, but we can and must disinfect the walls and component structural parts of the building.

It cannot be too clearly understood that while a room is occupied it is quite impossible to kill and destroy any infection or disease germs floating about in its contained atmosphere, without also killing those persons living in the room. But once the chamber is vacated we can, with some hope of success, endeavour to destroy all the infective microbes and their spores deposited in its dust on floors, ledges, or adhering to its walls and ceilings, by a combination of scrubbing, scraping, spraying, and the evolution of disinfecting gases. The most reliable chemical agents used for these purposes are formaldehyde, chlorine, and nitrous acid.

Formaldehyde may be used either in watery solution and applied to walls and surfaces in the form of a spray, or it may be employed as a vapour. The commercial form of formaldehyde is formalin, which contains 40 per cent. of formaldehyde. Two per cent. of formalin, or 3·25 fluid ozs. to a gallon of water, to which is also added 3 ozs. of glycerine to prevent polymerization, applied as a spray, is very effective in the disinfecting of walls, floors, ceilings, and other parts of houses or rooms. This statement, however, only holds good provided an efficient atomizer or spray be used, and that great care is taken to see that the liquid is brought into complete contact with the whole surface and no bare patches left. Employing the above formula, we have found that, for effective disinfection of walls, etc., at least two gallons of the solution must be used for each thousand square feet of surface to be sprayed.

Formaldehyde vapour, for use as a gaseous disinfectant, is usually obtained by volatilizing the solid form of formaldehyde or para-formaldehyde by means of heat in the presence of aqueous vapour in a special lamp. There are various forms of apparatus for its production, the more common being the Alformant lamps of Schering, in which tablets of paraform are burned. It is claimed that one of these tablets, when volatilized, is sufficient to disinfect 100 cubic feet of space; our experience indicates that, in order to ensure thorough disinfection of infected material exposed to formaldehyde fumigation, at least five tablets per 100 cubic feet should be converted into formaldehyde vapour, and we recommend not less than this quantity to be used.

Various other forms of vaporizers for formaldehyde have been suggested, but the greater number fail to secure sufficient penetrative power. Perhaps the best of the kind is Trenner's, which in our hands has certainly yielded good results. It works from

outside the door of the room to be disinfected, without pressure, and automatically. It consists of a heavy copper retort constructed on the lines of a modern tubular boiler, and from which a known quantity of formaldehyde solution can be rapidly and conveniently vaporized. The emerging vapour is practically superheated by the escaping products of combustion from the spirit-lamp beneath, and readily conducted by the elongated neck of the retort to the interior of a room, by passing the nozzle through the keyhole of a closed door. No attention is required after filling the apparatus and lighting the lamp, which, containing a definite amount of spirit, is allowed to burn itself out. We have found it unnecessary to hermetically seal small crevices or cracks, as the formaldehyde gas and water vapour are so highly superheated, evolved so rapidly, and in such volume, that penetration into all parts of the enclosed space is secured with a maximum germicidal action on all exposed surfaces within the room. The main essential for success is the vaporization of a sufficient volume of formaldehyde solution in relation to the size of the room. From our experience, this may be put at not less than nine fluid ounces (250 c.c.) of formalin, with 1 per cent. of glycerine, for each thousand cubic feet of space. In the case of very large rooms, it may be necessary to employ two or more of these vaporizers. It must be remembered that the vapour of formaldehyde is both pungent and irritating.

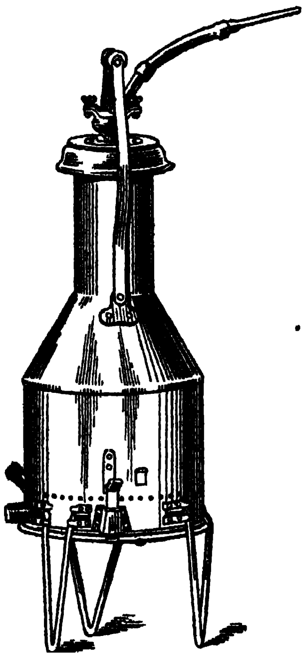


FIG. 73.—Trenner's formaldehyde disinfector.

Under circumstances in which a special vaporizer is not available, the following process has been put forward by H. V. Walker, in which he suggests the liberation of formaldehyde gas from its aqueous solution by the addition of lime as a dehydrating agent. In order to prevent the calcium hydroxide which goes into solution from converting the formaldehyde into alcohol and acid, aluminium sulphate is added, which forms an insoluble sulphate with the lime. In practice, the mixture is made by dissolving 20

to 25 pounds of commercial aluminium sulphate in five gallons of hot water, and mixing this solution with 15 gallons of formalin. Eight fluid ounces of this mixture and one pound of lime are to be used for every 1000 cubic feet of space to be fumigated. The lime should be in the form of coarse powder or lumps, and it is essential that it should slake rapidly with cold water. This method has the advantage of not requiring any special apparatus, of cheapness, and of freedom from risks of fire. Its success is doubtless due largely to the great rapidity with which the gas is evolved, a sufficient quantity to fumigate an ordinary room being liberated in from five to ten minutes. In municipal practice, the method is said to have given excellent results.

Chlorine is probably one of the best gaseous disinfectants we have, its power increasing with the amount of moisture present. It is given off from chloride of lime when moistened with a little dilute sulphuric acid, and placed in a shallow vessel. A very useful formula for generating enough chlorine for 1000 cubic feet of space is to place in an open dish 8 ozs. of common salt and 2 ozs. of manganese dioxide, and then pour over them 2 ozs. of sulphuric acid and 2 ozs. of water previously mixed together, and place the dish in a pipkin of sand. Notwithstanding its great efficacy as a bactericidal agent, chlorine can never come into general use, owing to its poisonous and irritant nature.

In place of evolving the crude gas from such an apparatus, chlorine in the nascent state may be generated in the places required by thoroughly washing all parts of a room with a 1 per cent. solution of bleaching powder. After the application of this solution, chlorine continues to be evolved so long as all the chlorinated lime has not been decomposed; its activity can be increased by adding an acid to the solution, or by saturating the air of the room with acid fumes from acidified water and by raising the temperature of the room. Eight ozs. of bleaching powder in 3 pints of water are sufficient for one washing over of the walls of a room measuring 10 feet in all directions. Three or four washings are desirable.

Nitrous acid is a very powerful oxidizing and disinfecting agent. It is a very irritating gas, and readily evolved by placing a piece of copper into some nitric acid and a little water. For 1000 cubic feet of space, the quantities should be—copper shavings, 1 oz.; nitric acid, 3 ozs.; water, 3 ozs.: the mixed acid and water to be poured upon the copper in a small jar. Some authorities regard nitric disinfection to be the worst of all methods; we do not consider it an ideal procedure, but have known its practical utility in circumstances of emergency.

The only other disinfectants which it is necessary to mention

here are sulphur dioxide and chinosol. The former has for many years had a great reputation for disinfection purposes. In the absence of moisture its germicidal power is low, and as the slightest covering will protect germs from its action, we consider that its routine use should be abandoned. Chinosol is a proprietary article which is non-poisonous and very soluble. Personally, we have had no experience of it, but used as a solution of 1 in 600 strength, in the form of a spray, it has been well spoken of by competent observers.

Of the many other reagents now in the market, and popularly regarded as disinfectants, the majority are really not so at all, unless used in very concentrated solutions; they are merely deodorants, or at most antiseptics or means of checking and delaying putrefaction. Much of this difficulty arises from the fact that there is no official control over the sale of disinfectants, other than that set forth in the Privy Council Orders of July 27, 1900, and June 5, 1902. The first order permits the sale, without control, of liquids containing less than 3 per cent. of phenol or its homologues as disinfectants, on the ground that such a fluid is not a poison within the meaning of the Pharmacy Act, 1868. In the second order, it is stated that liquid disinfectants containing scheduled poisons (which for present purposes are practically phenol or its homologues, in solutions of more than 3 per cent., and corrosive sublimate) shall be sent out in distinctive bottles. It is clear that these orders exercise no control over the sale of undoubted disinfectants such as mercuric iodide and formaldehyde. This anomalous state of affairs is largely due to the absence of any organized system of standardizing disinfectants. Any attempt at standardization must be based upon a bacterial rather than a chemical determination of efficiency, as although the strength of a preparation of phenol or its homologues can be ascertained with accuracy, there are many other equally good disinfectants which do not depend upon these acids for their germicidal efficiency. We hope to see this matter placed upon a satisfactory basis at no distant date. The difficulty is to determine what shall be the unit of comparison. Pure phenol has been suggested, and it is probable that this will be the most convenient standard to adopt, and that the strength or efficiency of any disinfectant will be expressed in multiples of carbolic acid performing the same work, the ratio, so obtained, being called the phenol coefficient. This coefficient will probably be found to vary with the same disinfectant in respect of its efficiency against different micro-organisms; in other words, certain reagents or preparations will be found to have a selective activity against special varieties of bacteria. We have already some evidence

in support of this view, but the time is not ripe for specific statements.

Practical Disinfection.—Although under the preceding headings the practical utility of the various means of disinfection has been more or less clearly indicated, it may be of value to briefly summarize these very necessary measures in respect of discharges or excreta, clothing, bedding, furniture, rooms, and drains, gullies, and refuse.

Of excreta and discharges.—These should be received into a vessel containing either carbolic acid solution (1 in 20) or izal solution (1 in 20) or cyllin (1 in 50), with the application of a further quantity of the disinfectant directly afterwards. In cholera, enteric fever, and dysentery, sterilization of the evacuations by steam heat is advisable if it can be done. In cholera the vomited matter should be treated in the same way as the stools. In diphtheria, scarlet fever, measles, whooping-cough, and phthisis, great care needs to be taken that all discharges from mouth or nose, and rags or handkerchiefs soiled by them, be adequately subjected to disinfection on these lines.

Of clothing and bedding.—All articles of little value should be burnt. Small articles may be boiled for an hour or longer. Bulky articles, such as blankets, bedding, mattresses, etc., should be subjected to moist heat in a proper disinfecting apparatus. In default of special appliances, sheets and clothing may be soaked in carbolic acid (1 in 20), or izal (1 in 20), or chloride of lime (2 ozs. to gallon), or cyllin (1 in 100), or formalin (2 per cent.), or perchloride of mercury (1 in 1000) for twelve hours, and then boiled and washed.

Of furniture and rooms.—This can only be carried out effectually when the room is unoccupied; therefore the first essential is evacuation, next all articles that can be disinfected by moist or dry heat or by soaking in some chemical disinfectant should be removed, and treated accordingly. All windows, chimneys, and orifices having been closed as tightly as possible, and all cupboards and drawers opened and exposed, the space or chamber should be fumigated in presence of moisture with either formaldehyde, chlorine, or nitrous acid for at least three hours.

On re-entering, open all doors and windows, and strip the walls of paper, burn the pieces, have the ceiling well limewashed, and scrub all floors, all woodwork, and furniture with either plain hot water and soft soap, or with bichloride of mercury (1 in 1000) or with formalin (2 per cent.).

In many cases, adequate disinfection will be secured by free perflation of air, and, in place of fumigation, the free use of a spray of either formalin or chinosol or mercuric chloride in the

proportions already stated to the surfaces of walls and furniture. We are disposed to consider this application by sprays of these disinfectants directly to infected surfaces as of far greater value than attempts to disinfect by gaseous means; it is the place itself, not the air of the place, we need to disinfect; the air can be readily changed by free ventilation.

In attempting to disinfect mortuaries and dead-houses, fumigation by chlorine or nitrous acid coupled with limewashing are the best procedures to adopt.

Of drains, gullies, and refuse.—The actual disinfection of drains and other places which receive offensive matters is impossible; the most we can hope to do is to deodorize. This can be done either by the liquid disinfectants already mentioned, or by solid chemical reagents, such as lime, quicklime, and chloride of lime. Even dry earth and charcoal will be found useful. So too will the various carbolic powders, which are mainly combinations of one or other of the phenols with either lime, silica, or alumina. Sulphate of iron (1 lb. to gallon) is a valuable agent for drain and gully deodorization.

CHAPTER VIII

PARASITES.

In addition to the various micro-organisms referred to in the last chapter, and which it was explained are now regarded as the cause of the different infectious or specific diseases, the human body is liable to the attacks of various other organisms. These organisms are both vegetable and animal, and according to the nature and function of the respective parts of the body which they attack, give rise to diseased conditions of varying severity. It is customary to speak of these living organisms, which are dependent upon or adventitious, as it were, to the human body as *parasites*.

The vegetable group of human parasites are almost exclusively met with on external parts of the body, and being of the nature of minute fungi, or moulds, they give rise to skin diseases of a more or less contagious character. Such are the various kinds of ringworm, chloasma, and thrush.

Ringworm is the popular name for a large group of skin diseases which have a certain family resemblance to each other, in that they often spread in the form of a ring or circle. All these

diseases are produced by species of fungi, and, as a rule, have strong predilections for the scalp and other hairy parts of the body. Being intensely infectious or contagious, these vegetable parasitic diseases are readily transferred from one person to another. Ordinary ringworm is sometimes epidemic in schools, spreading from child to child by contact or contagion. The typical disease consists of circular patches varying from a six-pence to a five-shilling piece in size or larger, having a slightly raised or scurfy surface, the hairs on which are dry, brittle, lustre-less, and broken off close to the scalp. This condition is caused by the fungus attacking the hairs, a fact easily shown by soaking a diseased hair in weak potash solution, and then examining it under the microscope, when it will be seen that the hair is invaded to a greater or less degree by the fungus called the *Trichophyton tonsurans*. Ringworm of the body is marked by the occurrence of red, scaly, itchy, and circular patches, and is excited by the same fungus as occasions ringworm of the scalp.

Favus, or scald-head, is another form of ringworm, caused by the fungus *Achorion Schonleinii*, and known by the presence of dry, light, cup-shaped crusts, out of which a hair sticks, and made up of fungus elements. Owing to the highly contagious nature of these skin diseases, care needs to be taken that they are recognized early, and treatment adopted. This consists in the killing of the parasite by means of repeated applications of iodine, or the use of germicides, such as corrosive sublimate. All infected hats, caps, or clothing should be destroyed by burning.

Chloasma is a skin disease marked by fawn-coloured patches, occurring in the parts covered by flannel, especially the front of the chest and root of the neck. These are often raised and occasionally itchy. They are caused by the fungus *Microsporon furfur*. The liberal application of soap and water usually suffices to remove this parasite.

Thrush, or the greyish-white circular patches seen in the mouths of young and feeble children, especially when artificially or improperly fed, is due to a species of mould called *Oidium albicans*. This mould is probably identical with the oidium of milk, since the use of turned milk or a dirty feeding-bottle or tube by a child is almost invariably followed by the appearance of this parasitic growth inside the child's mouth. The occurrence of these patches indicates, not only that a child is not in the best of health, but also that greater care is needed to be observed as to the freshness of the milk or food and the cleanliness of the feeding-bottles. Every speck or patch of this oidium should be wiped out of the child's mouth, by either the finger or corner of the handkerchief, and the gums and insides of the cheeks washed

over with either glycerine and borax, or with a solution of chlorate of potash.

The animal parasites which attack man are, for the most part, either insects which burrow into and attack the skin, or worms which infest the blood and internal organs. As will be seen subsequently, the most remarkable feature in animal parasites is the fact that their parasitism only represents a single phase in the life of the animal, and that while a few parasites, notably the parasitic insects, do not attain to sexual maturity until they have commenced to lead a free existence, the greater number of them, especially the worms, attain sexual maturity while in their parasitic stage, and therefore reproduce themselves in the body of their host.

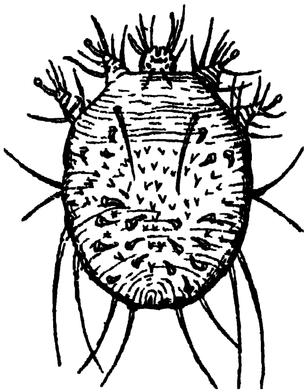


FIG. 74. *Acarus scabiei.*

Scabies, or itch, is caused by the burrowing into the skin of an insect called the *Acarus scabiei* (Fig. 74). This burrowing excites much itching and some rash. It is the female itch insect which thus burrows and causes the characteristic symptoms of this disease; for, burrowing beneath the cuticle, she lays her eggs at the end of the burrow, where they hatch, and the young insects then commence to burrow afresh in other directions. A very common place for itch to begin at is in the spaces between the fingers, and from out of the burrows, here or elsewhere, the acarus can be dug out by a needle, if carefully looked for. The irritation which these insects set up is most intense, and often gives rise to eruptions of pimples, blisters or pustules, which readily obscure the true nature of the affection. Owing to the ready means by which the itch insect can pass from one person to another, itch is eminently contagious, and the greatest care needs to be taken in separating those affected with the parasite from those who are free, and too, the most careful disinfection of all clothing which has been worn by the sufferer. For the actual cure of the itch, sulphur ointment is the best remedy, but needs to be supplemented by scrubbing the skin with soft soap and hot water. This scrubbing removes the loose scurf or scales of the skin, and helps the action of the sulphur by exposing the insect in its burrows.

The louse, or *pediculus*, may infest either the hair of the head

or the body, in both of which parts it gives rise to characteristic irritation. Lice in the hair are quickly killed by saturating the hair with an ointment of corrosive sublimate; but a difficulty often exists in destroying their eggs or nits, which adhere to the hairs by means of a gummy matter. This can usually be dissolved by means of methylated spirits, and the nits detached by careful combing. The constant use of warm baths, soap, and scrupulous cleanliness are essential aids to keeping away the pediculi. The clothes of those affected with the body variety require exposure for some hours to a dry heat of not less than 220° F., or else to be treated by one or other of the disinfection methods as detailed in the last chapter.

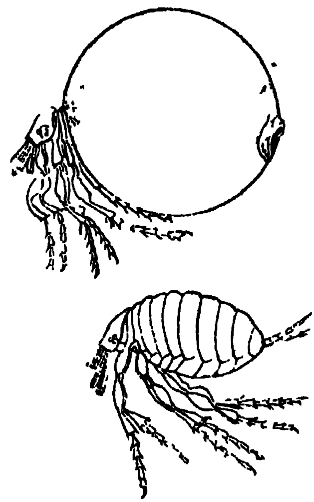


FIG. 75. *Pulex penetrans.* Female and male.

Fleas and bugs are, in a sense, parasitic, but possibly less so than a special variety of flea met with in some parts of the tropics, called the chigoe, or *Pulex penetrans* (Fig. 75). These insects give rise to considerable pain and irritation, accompanied by swelling of the parts attacked. It is only the female insect which gives rise to these symptoms. While the male retains the ordinary form and habits of a flea, the female bores her way into the skin of the foot in man, dogs, and other animals, and becomes, by the enormous development of the ovary, a simple motionless bladder embedded in the flesh, around which, in course of time, when the eggs have to be extruded, a certain amount of inflammation arises.

Guinea-worm, or the *Filaria medinensis*, is a formidable parasite, which, in some parts of Africa and India, gives rise to boil-like swellings and sores upon the ankles and legs. There has been much controversy as to how this worm gains entrance into man's system, some maintaining that the entrance is gained through the skin, either by a minute worm passing into a sweat-duct, or by a minute embryo coming in contact with a broken surface of skin; while others maintain that it always obtains entrance into the body by means of the drinking-water, and then works its way to the superficial parts at which it is generally found. At present this point is not definitely settled, but the

opinion is gaining ground that the parasite enters the human body by means of drinking-water. The worm is about $\frac{1}{10}$ inch in diameter, and usually from 1 to 3 feet long. Like many other animal parasites, its presence in the tissues of man is but a portion of its life-history, and to complete its cycle of existence it requires to pass into the tissues of some other living organism. So far as is known at present, the history of this worm amounts to this. The worm having gained access to man's body in an embryonic state, requires some nine months for its development, and it is only when the stage of maturity is reached and the eggs are about to be hatched that symptoms, in the form of an abscess or boil-like swelling, appear which in any way indicate its presence in the human tissues. The embryo which is emitted from man is aquatic in habit, and to further develop needs to pass into water. In this medium it meets with a fresh-water crustacean (*cyclops*), whose skin it quickly perforates, and in whose body it undergoes a certain degree of larval growth, and afterwards, with its host, the crustacean, reaches the inside of man, most probably by drinking-water. Its subsequent history in man is not known, but the inference is, that it burrows its way to the body surface in time to seek and secure an exit for its embryos into fresh water, in which medium they pass again through the changes already mentioned. This passing through one or more hosts, or individual living organisms, is characteristic of several other animal parasites of man, more particularly of the following, which mainly infest various parts of man's intestines or other viscera.

Filaria Sanguinis Hominis.—This is a minute hair-like worm, often reaching a length of 3 or 4 inches, found in the blood of men who have lived in certain tropical countries. It is considered to be the young form of another *filaria*-like worm, which, in the sexual state, is found in the lymphatics of the subcutaneous connective tissue of persons suffering from two peculiar diseases called chyluria and elephantiasis. The former is marked by periodic attacks, in which the urine becomes milky and, upon standing, coagulates. This condition has been traced to an admixture of urine with lymph, and in which immature filariæ are visible under the microscope. Elephantiasis is attended by an enormous enlargement of the limbs and generative organs. The life-history of the *Filaria sanguinis hominis* is very curious. The parent worm, or that usually associated with chyluria and elephantiasis, and known as the *Filaria Bancrofti*, lies in a lymphatic, and here emits her young into the lymph stream, along which they pass through the thoracic duct into the blood. In the blood, these embryos or young are known as the *Filaria sanguinis*

hominis nocturna, in consequence of their exhibiting there an extraordinary periodicity, abounding in the night time, but disappearing during the day, when they probably lie at rest in some abdominal or thoracic viscera. This periodicity is for some unknown reason an adaptation to the habits of the mosquito, which is the intermediate host of this parasite. The mosquito, as every one knows, is most active at night, and when it bites the human host, these filariæ curl round its proboscis and are then quickly transferred to its stomach. The greater number of the filariæ so swallowed by the mosquito are digested or destroyed, but a certain few undergo development inside its body, and, when the mosquito retires to some water to lay eggs, or to eventually die, these filariæ which have developed inside its body pass out by boring into the water, whence they get swallowed by man. Once inside the human stomach, the filariæ bore their way into the lymphatics, finally reaching their permanent abode in some distant lymph-vessel, where, as the *Filariæ Bancrofti*, they give rise to chyluria and elephantiasis, and breed, their progeny passing into the blood as before explained, till, released by the mosquito, they in their turn can complete their cycle of development. Such being the history of this remarkable parasite, it follows that, to prevent people getting affected with it, all water in filaria districts should be boiled and filtered.

Dochmius Duodenalis.—This is a short worm, about $\frac{1}{2}$ inch long, which attaches itself, often in large numbers, to the villi of the small intestine. It is common in Egypt and some parts of Italy, where, on account of the large amount of blood which it abstracts, it produces a serious and fatal form of anæmia known as ankylostomiasis. The mature eggs of the worm, on being discharged from the patient's intestines, undergo their primary stage of development in wet soil, being much favoured by a high temperature. In the warm damp earth the parasite leads a free existence, and assumes a slightly different shape to that which it presents when in the human bowel; instead of being rather short and stumpy, it is long and thin. From the soil to the well is but a short step, and, either in water—especially muddy water—or in earth adhering to food, this worm is transferred to the human alimentary canal. We can readily understand, in the light of these facts, how miners, brickmakers, agriculturists, and others handling damp and infected soil, may get infection through the mouth and possibly through the skin, as there is some evidence to show that infection may result by the direct passage of the larval forms through the skin, which not infrequently may be inflamed and be the seat of boils as the local effects of infection.

It is evident from the life-history of the ankylostoma, that any

attempts at prophylaxis are summed up in efforts to prevent the ripe larvæ entering the body. This can be secured either by personal hygienic precautions against ingestion of larvæ by the mouth and skin infection, or by precluding development of larvæ once the eggs leave man's body. Air-borne infection is most improbable; in mines and agricultural pursuits the most serious risk of infection is by dirty hands and dirty pipes. If contamination of the ground by human fæces can be prevented there is no possibility of ankylostomiasis spreading, as ripe larvæ then cannot reach those who would otherwise be exposed to infection. As the disease is absent as an endemic affection in any town or community with a moderately good system of excreta removal, the elaboration of some such system is clearly the simplest preventive measure.

Trichina Spiralis.—This is a small worm, varying from $\frac{1}{18}$ to $\frac{1}{9}$ inch in length, which attacks not only man, but also pigs and other animals, producing the disease known as trichinosis. In this disease the muscles present a number of ovoid cysts about $\frac{1}{70}$ inch in length, just visible to the naked eye, within which is coiled an immature trichina, not much more than $\frac{1}{40}$ inch long (Fig. 76). If by chance the tissue or muscle containing the capsules be eaten, the capsule is dissolved, and the young worms set free; these rapidly develop, and breed so rapidly that within a week the embryos of the trichina, by burrowing through the walls of the intestine, are able to find their way into all parts of the consumer's body, especially the muscles, in which they soon get encapsuled, to go through the same history again. When trichinosis occurs in man, it is generally due to the eating of the imperfectly cooked flesh of pigs suffering from the disease. It is somewhat common in Germany, where sausages, hams, and pork are more eaten than in this country. The symptoms of trichinosis are sickness, prostration, fever, and muscular pains. The mortality is often slight, but occasionally very high.

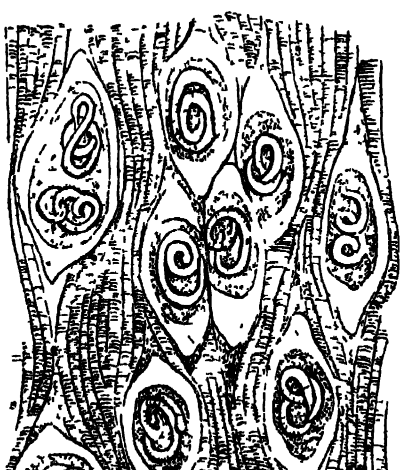


FIG. 76.—Muscle containing trichinæ.

Ascarides.—Under this name is included a large family of intestinal parasites. Of those affecting man there are three chief varieties: namely, the lumbricus or round worm, the thread worm, and a tropical kind called *Tricocephalus dispar*. The common round worm, or *Ascaris lumbricoides*, is very like an ordinary earth worm; it is pinkish in colour, tapering at each end, and some 6 inches long in the case of the males, and 12 inches in the case of the females. In man, it usually infests the small intestine, where it gives off large numbers of eggs, which are oval, nodulated, and about $\frac{1}{450}$ inch in diameter. How and where the eggs develop is not known, but it is supposed to be in some intermediate host, possibly an aquatic host; it is chiefly through water that they appear to reach man. The thread worm, or *Oxyuris vermicularis*, is a well-known human parasite, occurring in large numbers in the rectum. The female is about $\frac{1}{2}$ inch long, and the male $\frac{1}{4}$ inch. This worm gives off enormous numbers of oval, unsymmetrical eggs, each being $\frac{1}{500}$ inch long, and about half as broad. Improperly cooked or raw vegetables and water are the vehicles by which they directly reach man from outside. The *Tricocephalus dispar* is possibly the most common of all intestinal parasites affecting man in the tropics. Its eggs are voided into the bowel, and when discharged from the bowel the embryo is not differentiated; its development remains in abeyance until the egg is carried into water or some damp medium. This happening, development proceeds, and on the egg being swallowed by man in his drinking-water, the embryo is liberated in the alimentary canal, and attaches itself to the mucous membrane of the cæcum.

Bilharzia Hæmatobia.—This is another worm parasite, about $\frac{1}{4}$ inch long, which infests the veins of the large intestine, bladder, and kidney, and gives rise to inflammation of these parts with the passing of blood in the urine. It is prevalent in Egypt, South Africa, and elsewhere. The urine usually contains the ova, or eggs, of the parasite, which are not more than $\frac{1}{180}$ inch in size, having, commonly, a sharp spine at one end. The bilharzia probably gains access to the human body through drinking-water, as we can follow the ova in their escape by way of the urine from the body of the primary host. In water, these ova hatch into minute ciliated embryos, which have been traced into the bodies of certain fresh-water arthropodes, which appear to play the part of intermediate hosts for them, in the same way as certain fresh-water crustaceans do for the embryos of the guinea-worm. If the water be drunk containing these arthropodes, the transference of these embryos of the bilharzia to man is as simple as it is certain.

Tapeworms.—These are a very common form of parasite in man, both at home and abroad; their life-histories are also peculiar, as they show that these parasites pass through two distinct phases in two different hosts. One phase of their existence is that in which the head, or *scolex* as it is called, of the parasite, together with a kind of bladder-like expansion, is embedded in muscle or other solid tissue. The bladder-like expansion or cyst is called a *cysticercus*. If the flesh containing these cysticerci is eaten by any other animal, the scolex or head reaches the intestine of its new host or the consumer, attaches itself to the wall of the intestine, and loses its cyst. Gradually, now from this head grow a series of segments, each of which is square or oblong, and each of which, too, is provided with double sexual organs. The segments are often called *proglottides*, and the chain or complete series of them may reach a length of many feet, the whole constituting the tapeworm. Each of the segments produces eggs or ova; these escape into the host's bowels, and are voided by him in his excreta. Some of the ova become attached to grass, or other vegetables, and with them are consumed by an herbivorous animal in whose interior the embryo develops from the egg, and quickly burrows into its host's solid tissues, where it changes into a cysticercus, to go through the same train of changes if devoured by a carnivorous animal. If not so devoured it remains passive, and eventually perishes.

Fig. 77.—Head of *Tænia solium*.

Man is more subject to the tapeworm than to the cysticercus phase of the parasite's life. One of the most common tapeworms met with in man is the *Tænia solium*, which often grows to a length of 7 or more feet. Its head (Fig. 77) is about $\frac{1}{40}$ inch in diameter, and carries four suckers with a double circle of hooklets surrounding a prominence or *rostellum*. This tapeworm grows to its full size in about four months. The ova are spherical, $\frac{1}{170}$ inch in size. The cysticercus stage of the *Tænia solium* is called the *Cysticercus cellulosæ*, and is most commonly met with in the pig, in which animal it constitutes the affection known as "measles," and measly pork is the chief source of *Tænia solium* in man.

Another tapeworm, somewhat like the preceding, only longer, is that called the *Tænia mediocanellata*. It is not uncommon in

man. Its head is $\frac{1}{15}$ inch in diameter, resembles that of solium by having four suckers, but differs from it by not having either hooklets or rostellum. The eggs are oval, being about $\frac{1}{900}$ inch in diameter. Its cysticercus is called the *Cysticercus bovis*, because it occurs in the flesh of cattle; and the practice of eating underdone or raw beef is the chief source of the media-canellata tapeworm in man.

A tapeworm which is very common in Russia, Poland, Sweden, and Switzerland is that known as the *Bothriocephalus latus*. It is a very long tapeworm, often reaching 30 feet in length. Its head (Fig. 78) is ovoid, $\frac{1}{10}$ inch long, and marked by two longitudinal furrows or suckers, but without hooklets. Its eggs are oval, about $\frac{1}{370}$ inch in size, and fitted with a lid at one end. Its embryo is a ciliated organism found in river-water. Its cysticercus is supposed to be found only in fish, more particularly the pike.

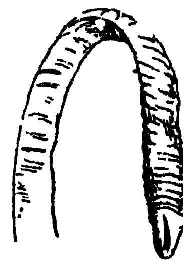


FIG. 78.—Head of *Bothriocephalus latus*.

Man is occasionally affected with a dangerous parasite under the name of *hydatid* disease. This commonly affects the liver, but may occur elsewhere. It is really the cysticercus stage of a tapeworm peculiar to the dog and wolf, and called the *Tænia echinococcus*. The head of this tapeworm is like that of the *Tænia solium*, only that it is but $\frac{1}{100}$ inch in width. The tapeworm is short, having, as a rule, but four segments, and the last segment only has reproductive organs. The echinococcus cysticercus in man differs from all other similar cysts, in increasing indefinitely in size and forms, within itself, secondary cysts, some of which again enlarge, and form, by a process of budding, new cysts within themselves. Not only man, but many animals, are at times affected with hydatid disease, in whom the echinococcus cysts are often spoken of as "bladder worms." It is not difficult to understand how cattle become infected; for the proglottides and eggs of the echinococcus tapeworm, voided so constantly, and in such large numbers by the dog, readily find access on to straw, grass, or even water, and with those articles of food and drink are consumed by the oxen. In the case of man, possibly the sequence of events is not much different. As with cattle, both proglottides and eggs of the tapeworm from the dog may in many ways be carried in food, especially uncooked vegetables, such as lettuces, or on the hands to the mouth, and thus reach the intestine. Probably, a greater risk of infection lies in the habit which dogs have of licking the hands and faces of their masters, and that often after they have been smelling and snuffing about other dogs.

These are considerations which should prevent our too familiar association with dogs, more particularly to avoid their licking us, and frequenting dwelling-rooms or kitchens, to say nothing of keeping them clean, and that their excrement is not allowed to remain about. Moreover, full precautions should be taken to prevent infection of dogs by embryos of echinococcus, as may occur in slaughter-houses, where the so-called bladder worms, or echinococcus cysts from slaughtered and infected animals, are often carelessly thrown down. It is needless to say that dogs eating such echinococcus bladders would soon develop them into sexually mature echinococcus tapeworms. It is with a view to avoiding such possible contingencies as the foregoing that the model bye-laws of the Local Government Board enact that "No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting, or otherwise."

Although the life-history of these various parasites is but imperfectly known, yet the remarkable facts, of which we have reliable knowledge, distinctly point to the great part which water plays in their diffusion to man, and the importance of avoiding all risks of infection by securing a good and pure water-supply; at the same time similar precautions are needed to see that all food is properly prepared and cooked before being eaten.

CHAPTER IX.

CLIMATE AND WEATHER.

Our term climate is derived from the Greek word κλίμα, a slope, and probably had its origin in the idea that the diversities of the qualities and conditions of our atmosphere varied according to the bending or sloping of the earth's surface from the equator to the poles.

The simplest plan of classifying climates is based upon geographical limits, and largely according to latitude. This at best is imperfect unless allowance be made for the influence of warm or cold sea currents, nearness or distance of mountain ranges, and large ocean areas. These latter in particular greatly affect rainfall and exposure to winds. Allowing for these modifying influences, and based upon the principle or limits of

latitude, a commonly accepted classification of climates is as follows:—

Warm Climates.—These include what are called tropical and subtropical climates, marked by high temperature, heavy rainfall, and more or less well-defined dry and wet seasons. Such climates are usually met with in places lying between the equator and 35° of latitude north or south of it.

Though possibly all the diseases usually attributed to the influence of warm climates are not rightly so, still they are peculiarly apt to be associated with such affections as heat-stroke, yellow fever, cholera, dengue, liver abscess, dysentery, small-pox, and various forms of malarial fever, while scarlet fever and measles are comparatively rare.

Temperate Climates.—These have a mean temperature of 60° F., often with great extremes: four well-defined seasons, usually most rainy during autumn and winter, and the geographical limits of from 35° to 50° of latitude.

Cold Climates, or those belonging to regions situated between 50° of latitude and the poles. In them the summer is short, often lasting but a few weeks, while the winter is long. Snow is extensive, but of rain there is little or none.

The diseases of temperate climates are mainly those of everyday English life; while in the cold climates scurvy and scrofula are the principal affections which can be directly attributed to climate. The former arising from a deficient supply of fruit and vegetables, and the latter from the overcrowding and general poorness of living which prevails. Just as diseases of warm or hot climates have an affinity for the abdominal organs, so have the diseases of temperate and cold climates an affinity for the thoracic organs.

Mountain Climates.—These are peculiar, being marked by extremes of temperature, great clearness and rarefaction of the atmosphere, and lessened atmospheric pressure.

Mountain climates are peculiarly favourable to those having imperfect chest development, with hereditary or other tendencies to consumption; but are unsuitable for those troubled with chronic bronchitis or acute diseases of the lungs, kidneys, liver, or brain. The peculiar effects of mountain climates appear to be due to the increased aeration of the blood which takes place during the act of breathing mountain air, and as a result of this, these climates are best suited for those capable of taking abundant exercise, and distinctly hurtful to the aged and very feeble.

Marine Climates are those prevailing upon islands, capes, and sea coasts, in which the temperature is remarkably equal, rarely reaching extremes, and in which, owing to the increased moisture

and rainfall, a certain softness of atmosphere is experienced. The climates of Great Britain, Norway, and Iceland may be taken as types of these so-called marine climates.

The principal diseases which appear to be in any way peculiar to marine climates are rheumatism and the various affections of the lungs and air passages, the greater part of which may be due to the dampness and constant weather changes which are so characteristic of these climates.

The multitudinous effects which climates have upon health have long been recognized, and have constituted one of the most difficult questions which nations and governments have had to consider in regard to schemes of colonization, location of communities, and the movement of armies. So great is the influence of climatic conditions upon health, that it is probable that many of the divisions of the human race owe their principal and essential characters to its continuous action through successive generations. Note the difference between an Englishman and an Italian, or between a German and a native of India. These effects of climate appear really to be the expression or result of the influences of all the various elements or factors and conditions which go together to make a climate. Such are temperature and sunshine, rainfall and moisture, wind and atmospheric pressure or density. The systematic observation and study of these various phenomena constitute the science of meteorology.

Temperature.—One of the most remarkable facts in connection with man is that when in health he is able to maintain his normal or standard body heat of 98° to 99° F under the most extreme and opposite climatic conditions. This, of course, is not always the case, for at times both extreme cold and heat profoundly affect man's physiological condition. Thus, prolonged exposure to extreme cold causes excessive contraction of the smaller blood-vessels, resulting in so great a shutting off of the blood supply to the extremities that they become gangrenous or frost-bitten. At the same time, if the exposure be very prolonged, the body loses all power of reaction, lassitude sets in, followed by deep sleep, usually ending in insensibility and death. More rarely the languid state is replaced by one of delirium not unlike intoxication.

Except perhaps in the tropics, the general effect of direct sun's rays on the body is beneficial; but prolonged exposure to great heat, whether in the sun or in the shade, is accompanied by pronounced physiological disturbance. Some experiments go to show that the body heat itself is increased $\frac{1}{20}$ degree for each degree (Fahrenheit) rise in the air's temperature, while the respirations of those living in hot countries, though at first (some six

months) increased, are afterwards so much lessened in frequency that the entire respiratory function is reduced by about 18½ per cent. Much of this lessened respiratory function in hot climates is said to be due to the fact that with a high temperature the quantity of oxygen present in the air is diminished. Thus, a cubic foot of dry air at 32° F. weighs 566·85 grs., which, neglecting the slight amount of carbon dioxide present, gives in that cubic foot of air 436·5 grs. of nitrogen and 130·35 grs. of oxygen. Assuming that a man at rest breathes 16·6 cubic feet of air per hour into his lungs, he will at 32° F. receive 2164·2 grs. of oxygen per hour. At a temperature of 100° F. (which is not unusual in the tropics) a cubic foot of dry air weighs 498 grs., and is made up by weight of 383·5 grs. of nitrogen and 114·5 grs. of oxygen. Therefore in an hour, breathing as before, the man would receive 1901 grs. of oxygen, or nearly 12 per cent. less than he would breathe in at the lower temperature. The action of the skin is increased in hot countries by as much as 24 per cent., but the water exhaled by the breath and passed off by the kidneys is proportionately reduced. In hot climates, the general functions of the whole body become impaired, notably the nervous system and digestive organs, which, from being the seat of more or less increased action, are peculiarly liable to become congested and enlarged. The essential requirements for the bearing of great heat by the body is the maintenance of abundant perspiration; the moment this fails the heat equilibrium is disturbed, and the body heat rises rapidly, accompanied sooner or later by insensibility and death from heat-stroke.

Owing to our senses being insufficiently acute to measure slight changes in temperature, we have to make use, for this purpose, of instruments, called thermometers, which indicate, by means of the expansion or contraction of bodies under heat, its varying degrees of intensity. Liquids are the bodies best suited for this purpose in the construction of thermometers—the expansion of gases being too great, and that of solids too small. Of liquids, mercury and alcohol are practically the only ones used; the former because it boils only at an extremely high temperature, and freezes at a very low one, and the latter because at atmospheric pressure it does not solidify at the greatest known cold. For these reasons, mercury is used for recording high degrees of heat, and alcohol for low temperatures, the alcohol when so used being generally coloured. Although there are many varieties of thermometers, they can practically be divided into three kinds, namely, the ordinary, the registering, and the recording.

Ordinary thermometers consist of a capillary glass tube, at

the end of which is blown a bulb or reservoir. The manufacture of a thermometer, to ensure accuracy, is one of great delicacy and care; in the first place, the tube must be divided into parts of equal capacity, or *calibrated*, as it is called; next, it must be filled and finally graduated for the construction of the scale. Just as a foot-rule is divided into a number of equal divisions called inches for comparison of length, so is a thermometer marked into a number of parts of equal capacity for the comparison of temperatures, called degrees. Sometimes the scale is marked upon the thermometer stand, but in the best and more accurate ones it is marked on the actual stem.

Since ice constantly melts at the same temperature and distilled water under an atmospheric pressure of 29·92 inches, and in a metal vessel always boils at the same temperature, these two temperatures are taken as the limits of the scale, and the interval between them is taken as the unit for comparing temperatures, just as a foot or yard are taken for comparing lengths. The melting-point of ice or first fixed limit is usually called zero, and the other fixed limit the boiling-point. On the continent of Europe, the scale of a thermometer is divided into 100 parts or so-called Centigrade. This division is really the simplest, and now generally used in this country in connection with all scientific work. In this scale, the zero or freezing-point is at 0 degrees, while the boiling-point is at 100 degrees. The degrees are usually designated by a small cypher placed a little above on the right of the number, thus $20°$, while to indicate temperatures below zero, the minus sign is placed before, thus $-10°$, or ten degrees below freezing.

Another scale, known as Réaumur's, is used in Russia and some other parts of the Continent; in it the fixed points are the same as in the Centigrade: but the interval between them is divided into 80 instead of 100 parts; that is to say, 80 degrees Réaumur equal 100 degrees Centigrade, or 1 degree Réaumur is $\frac{5}{4}$ of a degree Centigrade, or 1 degree Centigrade is $\frac{4}{5}$ of a degree Réaumur. Consequently, to correct Réaumur degrees into Centigrade ones it is necessary to multiply them by $\frac{5}{4}$. Similarly, Centigrade degrees are converted into those of Réaumur by multiplying them by $\frac{4}{5}$.

In England and America, for general use, the thermometric scale invented by Fahrenheit is still employed. In this scale the higher fixed point is, like that in the Centigrade and Réaumur scales, that of boiling water; but the lower fixed point, or zero, is not the temperature of melting ice, but that obtained by mixing equal parts of snow and sal ammoniac, and the interval between the two is divided into 212 parts or degrees. The zero

temperature on this scale is lower than that of melting ice, with the result that when a Fahrenheit scale thermometer is placed in melting ice, it stands at 32 degrees, and, therefore, 100 degrees on the Centigrade scale and 80 on the Réaumur equal 212 less 32, or 180 degrees on the Fahrenheit, or 1 degree Fahrenheit equals $\frac{5}{9}$ of a degree Centigrade, and $\frac{4}{9}$ of a degree Réaumur. For the conversion of any given number of degrees Fahrenheit into Centigrade or Réaumur degrees, the number 32 must be first subtracted in order that the degrees may count for the same part of the scale, and the result then multiplied by the relative value of the two degrees. Conversely, Centigrade and Réaumur degrees may be converted into Fahrenheit by adding 32 after multiplying by the ratio value. Thus, by the use of the following formulas—

$$\tfrac{9}{5}\text{C.} + 32 = \text{F.} \qquad \tfrac{9}{4}\text{R.} + 32 = \text{F.}$$
$$(\text{F.} - 32)\tfrac{5}{9} = \text{C.} \qquad (\text{F.} - 32)\tfrac{4}{9} = \text{R.}$$

we can show that 20° F. equals $-6°{\cdot}6$ C., or $-5°{\cdot}4$ R., and that 20° C. equals 68° F., and 20° R. equals 77° F.

A good mercury thermometer should answer to the following tests. When completely immersed in melting ice, the top of the mercury should exactly indicate zero or 32°, according as to whether the scale be Centigrade and Réaumur or Fahrenheit; and when suspended in the steam of water boiling in a metal vessel with the barometer at 29·92 inches, the mercury should be stationary at either 100° or 212° according to the kind of scale. The value of the degrees should be uniform, as shown by a detached piece of mercury occupying an equal number of degrees in all parts of the tube.

Owing to the temperature constantly varying, the actual reading observed has but a limited value, so that registering thermometers are required; of these there are two kinds in common use, namely, those known as minimum and maximum thermometers.

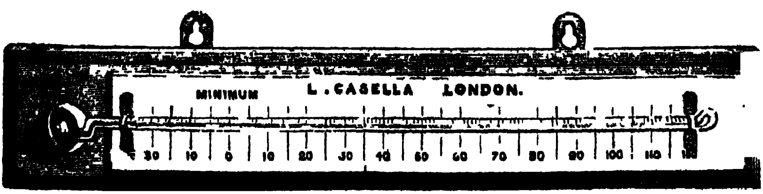
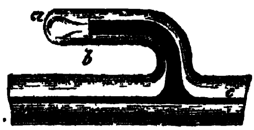


FIG 79.—Ordinary minimum thermometer.

The minimum thermometer (Fig. 79), or instrument for registering the lowest temperature during a given period of time,

is sometimes known as Rutherford's minimum. In principle it is very simple, the bulb and part of the stem being filled with coloured alcohol in which a little glass or metal index is placed. When the temperature falls, and the alcohol contracts, the capillary attraction of the liquid draws the index back with it towards the bulb; but when the temperature rises again, the alcohol passes the index, and leaves the extremity of it farthest from the bulb at the lowest temperature reached. The instrument, after having been read, is readily set up by partially inverting it and letting the index fall to the top of the spirit column; it is then hung up in a horizontal position. Occasionally air bubbles appear in the alcohol and fix the index, while at other times some of the alcohol volatilizes and condenses at the top of the tube. Both these faults can be easily cured by holding the thermometer bulb downwards and swinging it rapidly round; this will usually cause the air bubbles to disperse, and displace any condensed alcohol from the top of the tube. If, by chance, as the result of this procedure, the index be thrown into the bulb, a little tapping and patience will bring it out again.

To avoid the annoyance arising from breakage of the column by bubbles of air, and from vaporization in alcohol



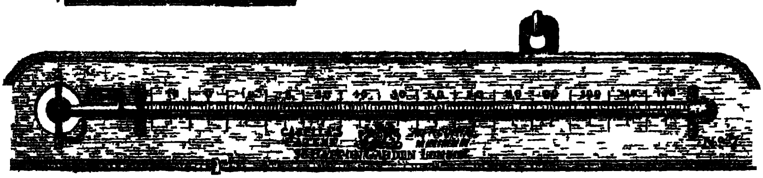


FIG. 80.—Mercurial minimum thermometer.

minimum thermometers, Casella has invented a *mercurial* minimum thermometer (Fig. 80). In this instrument there is no steel or other index employed; its general form is shown in the figure, *c* being a tube with large bore, at the upper end of which a flat glass diaphragm is formed by the abrupt junction of the small chamber *ab*, the inlet to which at *b* is larger than the bore of the indicating tube. The result of this is that, having set the thermometer, the contracting force of the mercury in cooling withdraws the fluid in the indicating stem only; whilst on its expanding with heat, the long or indicating column does not move, the increased bulk of mercury finding an easier passage

through the larger bore into the small pear-shaped chamber attached. To set this instrument, it is necessary to raise or lower the bulb end, so as to cause the mercury to flow slowly, until the

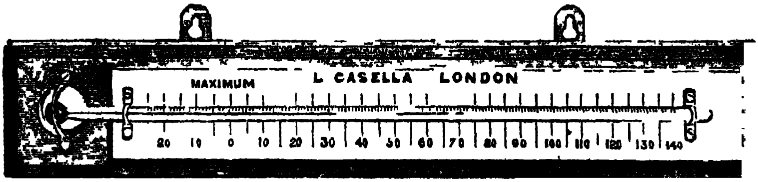


FIG. 81.—Maximum thermometer.

greater part of the tube *c* is full and the chamber *ab* quite empty; if at any time mercury will not readily flow from the small chamber as above, a tap or jerk with the hand will cause it to do so.

Of maximum thermometers (Fig. 81), or those registering the highest degrees of heat during any given time, there are two in very general use, namely, Negretti's and Phillips's. Both these instruments have mercurial columns, a detached portion of which serves as an index for the highest temperature reached. In Negretti's, the detachment is made by means of a slight contraction of the tube, which, while allowing the expanding mercury to pass when the temperature is rising, is sufficient to overcome the natural cohesion of the metal, when contracting, to prevent it drawing it back on cooling. In Phillips's, the detached portion of the mercurial column is separated from the rest by a bubble of air. Both these instruments are placed horizontally, and both can be re-set by lowering the bulb, and then either gently tapping or swinging the thermometer.

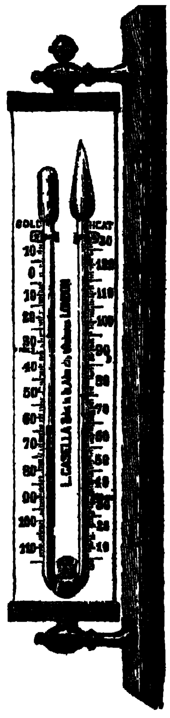


FIG. 82.—Six's thermometer.

Previous to the invention of these minimum and maximum thermometers, a registering instrument known as Six's thermometer (Fig. 82), from the name of its inventor, was much used, and is so now. The tube of the instrument is long and U-shaped. One limb constitutes the cold tube, and has at its extremity a bulb, while the other limb is the heat tube, having at its top or end a small chamber in which is confined some air. The middle portion of the tube contains

mercury extending round the bend and part of the way up each limb. The bulb and both tubes or limbs above the mercury contain alcohol. Inside the alcohol are two steel indices, one being in the cold tube and the other in the heat tube. These are readily set, or caused to rest gently upon either column of mercury, by moving them by means of a magnet. This being done, if the temperature rise, the alcohol in the bulb will expand and push down the mercury in the cold leg, but raise that in the heat leg, and by so doing drive up the index in it until the temperature ceases to rise, when the point of maximum heat will be indicated by the lower end of that index. On a fall of temperature precisely the reverse will happen, for then the spirit within the bulb will contract, and the pressure in the air chamber at the top of the heat leg will force the mercury down in it, but up in the cold limb, while the cold index will continue to go up so long as the temperature continues to fall. Of course the scales read downwards on the cold leg and upwards in the heat one, and in each the lower end of the index shows respectively the lowest and highest temperature reached since the instrument was last set. The presence of the air chamber makes a Six's thermometer unsuited for travelling, and necessitates the vertical position.

Of recording thermometers, the cheapest are those of Cripps or Richard. The bulb is a large curved flattened tube, filled with a liquid which tends to straighten with an increase of heat, and this being connected with a long lever in such a manner as to rise with increase of temperature and to fall with decrease, marks a tracing line upon a revolving cylinder. This cylinder depends upon a clockwork arrangement, and can be wound up, started, and left untouched for given periods of time, at the end of which records of temperature will be found for every instant during the period. As the curvature of the tube and the spring mechanism are apt to alter, these instruments need to be corrected and compared periodically with an accurate mercurial thermometer.

In all efforts to compare climates or temperatures, it is not only necessary to have accurate thermometers, but also to place them so far as possible under similar conditions; for this purpose uniformity of exposure is obtained by placing or exposing thermometers in certain standard screens. The thermometers already described are invariably kept in the shade, and carefully protected from all direct rays of the sun and effects of reflected or radiated heat from walls and buildings. Owing to this fact, these instruments are sometimes spoken of as shade thermometers in contradistinction to others which will be described later on, and known as sun thermometers. The screen or arrangement for shade

thermometers is a hut or box known as Stevenson's screen (Fig. 83). It is made of stout boards, with a ridge roof and louvred sides open below, and standing some 4 feet off the ground on four legs. It is placed where it will be freely exposed to the movements of the air, and at least 20 feet away from any house or building. All thermometers should be read once daily, say 9 a.m., when the highest and the lowest temperatures of the previous twenty-four hours will be recorded.

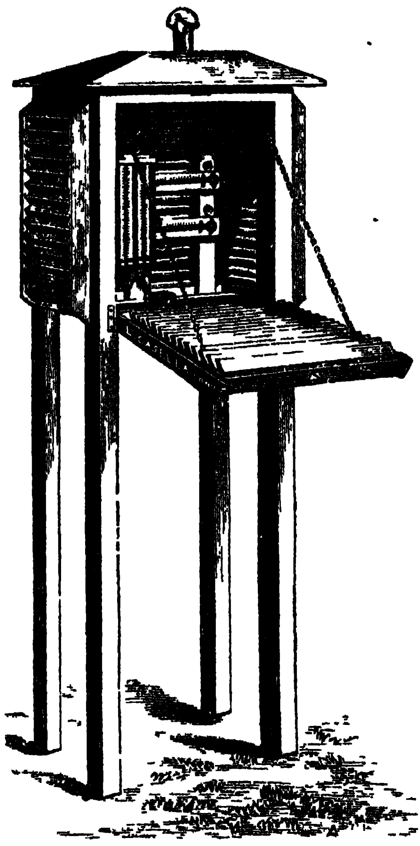


FIG. 83.—Stevenson's screen.

The mean temperature of the day may be obtained by taking a single reading at 9 p.m., or by taking the mean of two readings at 9 a.m. and 9 p.m., or by taking the mean of the maximum and minimum recorded temperatures; this is usually correct for winter, but in summer may be as much as 2° too high. A more accurate result may be obtained for the British Isles by employing the following method, recommended by the late Rev. Dr. Lloyd: Multiply the difference between the observed maximum and minimum by the proper factor obtained from the following table, and add the product to the minimum:—

Month.	Factor.
January and December	0·520
February and November	0·500
March and October	0·485
April and September	0·476
May and August	0·470
June and July	0·465

The only true mean can be obtained by taking a mean of hourly readings. The weekly, monthly, and annual means are derived from daily means. As a rule, the lowest temperature is recorded at 3 a.m. and the highest at 2 p.m., but of course proximity to the sea or elevation and influence of latitude considerably affect these observations.

Some idea of the intensity of the sun's heat is obtained by means of what are called *solar radiation thermometers* or maximum thermometers placed direct in the sun's rays. In order to avoid loss of heat by reflection from the bright glass surface of the bulb, this and one inch of the stem is coated with lamp-black, and this again, to protect it from being washed off by rain, is placed in a glass case out of which air has been pumped to make it a vacuum. Unfortunately, the presence of the outer glass covering largely interferes with the cooling influence of wind, which materially affects the distribution of heat by the sun in Nature. Notwithstanding this theoretical defect, the blackened bulb maximum thermometer *in vacuo* is the best instrument we have for measuring the amount of heat given out or radiated by the sun. The instrument (Fig. 81) is exposed freely to the sun and air by fixing it horizontally 4 feet above the ground, well away from trees or walls, and with its bulb, in this country, pointing south-east. The heat recorded by such an instrument will be the temperature at which an equilibrium or balance is established between the heat produced by the direct rays of the sun on the bulb, and the cooling caused by radiation or loss of heat from the bulb to the glass jacket or covering; this latter, of course, will have practically the same temperature as that of the air. It follows, therefore, that the excess of the temperature of the black bulb over that of the outer air, as registered by the maximum shade thermometer, will be an approximate measure of the power of the actual sun's rays, or, in other words, the power of the sun's radiation of heat. Thus, suppose the black bulb thermometer show a reading of 116°, and the shade or air maximum be 76°. The difference between them of 40° will be the approximate

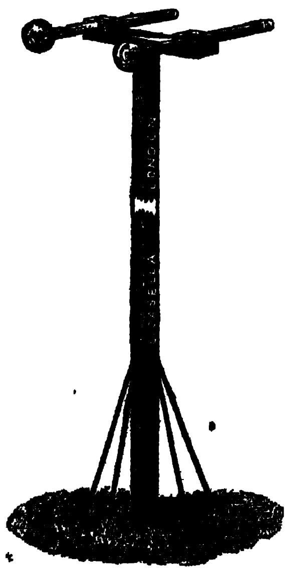


FIG. 84.—Solar radiation thermometer on stand.

measure of the sun's intensity. As an alternative method, it has been suggested to expose alongside of the black bulb *in vacuo* a similar thermometer also *in vacuo*, only with its bulb bright, and to register the difference between the readings of the two instruments as the amount of solar radiation. It has been objected, with some reason, to both these methods, that the indications of the black bulb or sun maximum thermometer are not of much value, because in the first place the sun's rays do not necessarily have their greatest power at the hour of maximum air temperature, but much earlier, and that to obtain reliable results we should therefore subtract from the black bulb reading, not the maximum, but the actual air temperature at the moment the black bulb reaches its highest point. What is really wanted is a measure of the total heat received from the sun, not a record of its maximum intensity at any particular time.

Not only is there a constant gain of heat by the earth from the sun, but there is also a more or less constant loss of heat from the earth and from all objects on it. This loss of heat is spoken of as *terrestrial radiation*, and is very much greater when the sky is clear and the air dry than when overcast with clouds, or when much moisture is present in the atmosphere. It is owing to the comparative rapidity with which soil covered with grass and vegetation radiates heat into space that the air over grass-plots and lawns is colder than that in immediate contact with or over bare flower-beds and gravel-walks. This loss of heat from

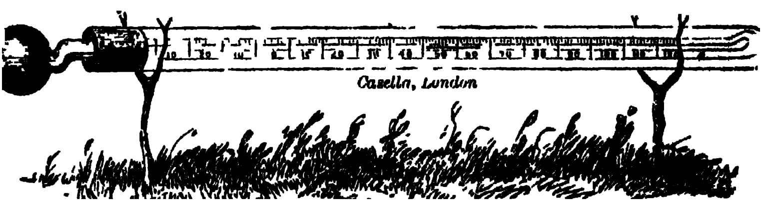


FIG. 85.—Minimum thermometer on grass for recording terrestrial radiation.

the earth is most marked where the disturbing influence of air currents is least, hence it is usual to place a thermometer intended to measure radiation upon the ground. The amount of the loss of heat by radiation is determined by placing a minimum thermometer, as already described, on short supports some 4 inches off the ground on a plot of grass (Fig. 85). The difference or defect of this minimum temperature below that of the air minimum in the shade is taken as the amount of terrestrial radiation.

Sunshine.—The duration of the sunshine is a very important

factor in all climates, and the extent of this duration is recorded by either what is called Whipple-Casella's apparatus or by Jordan's. The former (Fig. 86) is mainly a glass sphere so mounted that when the sun shines its rays are focussed as by a lens upon a strip of cardboard, with the result that a burnt track or hole is left for such periods of time as the sun shines. The

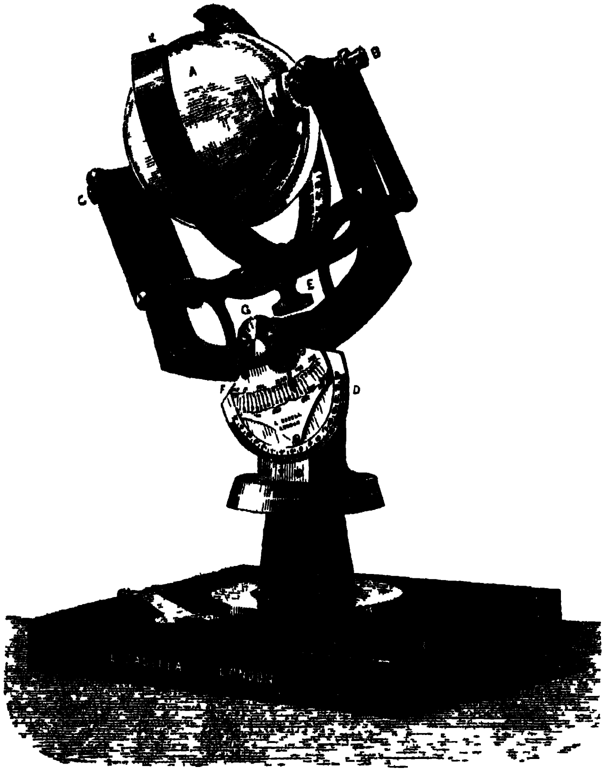


FIG. 86—Whipple Casella sunshine recorder.

cardboard is so placed in the instrument that definite sections of it correspond to periods of time and hours.

Jordan's instrument is, strictly speaking, rather a recorder of sunlight than of sunshine. It consists of a circular box in which some sensitive photographic paper is placed, and the sunlight entering through a slit leaves a varying record of its duration and intensity. The paper can be readily "fixed" by washing in clean salt water.

Rainfall.—No factors have more influence upon the suitability or unsuitability of the climate of any particular country than the amounts of its humidity and rainfall. The *physical cause* of rain is the sudden chilling of comparatively warm air, more or less laden with moisture, either by its ascent into the upper and colder regions of the atmosphere, or by its impact against cold mountain slopes, or with the colder surface of the ground. The former cause is more potent in the summer, the latter in winter. It was formerly supposed that rain was largely caused by the mixture of masses of air of different temperatures. But, even supposing that any such admixture did take place, a comparison between the units of heat set free by condensation and the weight of aqueous vapour per cubic foot of air at any two given temperatures—one high, the other low—shows that the mixture of volumes of air cannot be very effective in causing precipitation (Hann). In fact, the latent heat set free in the process of condensation largely prevents that fall of temperature which is assumed to take place and to cause a rainfall.

The amount of rainfall is measured by an instrument called a rain-gauge, which, in its simplest form, is a copper funnel leading to a can or other receiving vessel (Fig. 87). In this country the funnel is usually circular and 8 inches in diameter, so that its area in square inches is accurately known. Having entered the funnel, the rain passes down a long and narrow tube, which at its end is curled upward to check evaporation, into a metal-collecting vessel. The rain, having been collected in the receiver, is measured in a graduated glass vessel, the divisions of which correspond to half-inches and tenths. The measuring vessel is divided proportionately to the area of the gauge, the diameter of which should always be some simple unit, like 5 or 8 inches, so that if the original measure get broken, a new one can be readily improvised and graduated. Thus, take an 8-inch gauge, the diameter being 8 inches, its receiving area is 50·26 square inches; therefore, 1 inch of rainfall, or rain 1 inch deep over a town, would deposit in that particular rain-gauge 50·26 cubic

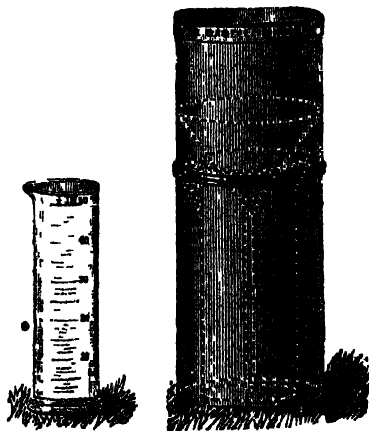


FIG. 87.—Rain-gauge and measuring-glass.

inches of water, or $29\frac{1}{2}$ fluid ozs. Therefore, if $14\frac{3}{4}$ fluid ozs. of water be poured into the proposed measuring glass, and the vessel be marked with a line at its level, that line will represent the graduation of $\frac{1}{2}$ inch of rain; subdivision markings are similarly made for tenths and hundredths of an inch.

In the absence of a properly constructed rain-gauge, the amount of rainfall can be readily measured in any receiving vessel, provided its receiving area is known, by measuring the volume collected in either fluid ounces or cubic centimetres, and making the calculation on the basis of the facts that 1 fluid oz. equals 1·728 cubic inch, and that 1 c.c. is 0·061 cubic inch. Thus --

$$\frac{\text{cubic centimetres of rain collected} \times 0{\cdot}061}{\text{area of receiving vessel in square inches}} = \text{inches of rain,}$$

$$\text{or, } \frac{\text{fluid ounces of rain collected} \times 1{\cdot}728}{\text{area of receiving vessel in square inches}} = \text{inches of rain.}$$

More rain is collected on the ground than on the top of a building, or on a stand at a height above the ground. For this reason the best place for a rain-gauge is on the ground in a well-exposed position, with the rim about 1 foot above the earth. A rain-gauge should never be placed upon a house-roof, unless, as in towns, no sufficiently open space is available. The spot on which a rain-gauge is exposed should be clear of all objects whose height is greater than their distance from the gauge. Rain should not be collected in the measuring glass, as it is liable to break, especially during frosts. Snow or hail can be measured by thawing the quantity collected and measuring the water which results. To avoid snow being blown out of the gauge, the upper edge of the funnel is usually fitted with a vertical rim about 6 inches in depth, and ground to a fine edge on the top.

The amount of rain which falls varies, of course, very much with the place; but in determining the average fall at any station, it is necessary to deal with observations extending over long periods. In England and Wales, the average rainfall each year is 33·76 inches; in Scotland, 46·56 inches; in Ireland, 38·54 inches. The average annual rainfall for the United Kingdom is 37·30 inches; for Great Britain, 36·69 inches. On the east coast of England not much more than 20 inches of rain falls in a year, while on the west coasts of both Scotland and Ireland it averages as much as 60 or 80 inches; in some parts of Cumberland as much as 150 inches a-year have been known to fall. It is very rarely that more than 1 inch of rain falls anywhere in Great Britain in one day; though occasionally as much as 5 inches have

been known to fall. For furnishing meteorological returns, a minimum record of 0·01 inch is considered as characteristic of a rainy day in this country.

Humidity.—The question of the amount of moisture in the air is somewhat complicated, and is usually spoken of as the degree of humidity. It was explained in an earlier chapter that water is constantly evaporating into the air, and that the amount of water or moisture which the air can hold or retain is constantly varying with its temperature. Thus at 32° F. a cubic foot of dry air can only take up 2·10 grs. of water, while at 100° F. it can take up as much as 19·84 grs. When air is so full of moisture that it can contain no more, it is said to be saturated. In this country the air upon an average contains about three-fourths of the amount of water needed to saturate it—that is, it has an humidity of about 75 per cent.; but if the air containing this amount of moisture be cooled down, it will reach a degree of heat at which that same amount of moisture will suffice to saturate it, and if cooled still more, it will reach a temperature insufficient to retain that moisture, with the result that it must part with some of it, the amount so parted with being precipitated or deposited as rain, snow, mist, or dew. For instance, 100 cubic feet of air three parts saturated with moisture at a temperature of 70° F. would hold 600 grs. of water; if for some cause or other the temperature of that 100 cubic feet of air were reduced to 61° F., that volume of air would become quite saturated, because at that temperature it could only hold 600 grs.; and if the temperature were still further reduced, say to 56° F., it could only retain 500 grs. of moisture; therefore the difference between 600 and 500 grs., or 100 grs. of water, would be released or deposited as mist, dew, or rain.

It has been pointed out by some observers that occasionally, in perfectly pure air, a pressure of vapour may be maintained greater than that corresponding to the temperature of saturation (Aitken). In fact, that condensation will not in general begin unless some nucleus is present to which the particles of water can attach themselves. It is on the presence of solid particles of dust in the air that the formation of mists and fogs depends, the precise degree of mist or fog depending on the amount of dust present, and on the size and constitution of the particles. When the number of dust particles is large or their size considerable, and the quantity of vapour condensed is small, we get the phenomenon of a town, or so-called dry fog. The condensation of water upon invisible particles so increases their size as to make them visible. Often in the case of town fogs their obviousness is not so much due to the action of the moisture condensed on

the particles as to the excessive size and quantity of the particles themselves. What are known as sea fogs probably occur in air which is comparatively dry, because the dust in their case consists largely of salt grains derived from spray or surf, and which have a great affinity for moisture. If the quantity of condensed moisture is large, or the amount of dust and other solid nuclei small, we get what is called a mist, and it is merely a question of the degree of the moisture present which determines where the mist ends and actual rain begins.

The formation of dew is precisely analogous; in this case the solid substance on which the moisture is precipitated or condensed is the surface of the ground, or a blade of grass, and not solid nuclei like soot or dust floating about in the air, as in the formation of fogs. Owing to the rapidity with which the earth, under certain circumstances, loses heat by radiation, as, for instance, on a fine clear night, the strata of air containing

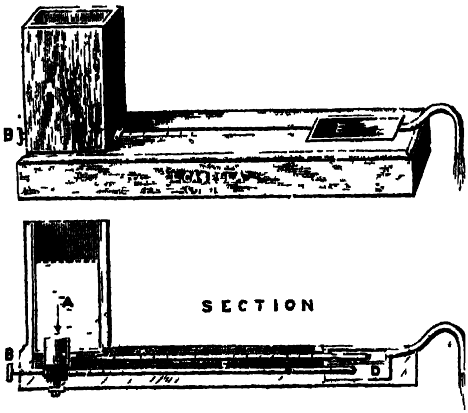


FIG. 88.—Dine's hygrometer.

moisture which are in contact with the cooling earth, themselves become reduced so much in temperature that they are no longer able to retain their water vapour, but actually lose it by condensation upon the ground, where it constitutes what we call dew. The particular temperature at which air saturated or loaded with moisture deposits its water is called the *dew-point*. It is from the determination of this dew-point that the weight of water present in the air (or, in other words, the percentage of saturation of the air for the existing temperature) is calculated. This, of course, expresses the degree of humidity.

For the determination of the temperature of the dew-point,

certain instruments called *hygrometers* are used. Of these there have been many varieties. A very ingenious instrument of this kind is that known as Dine's hygrometer (Fig. 88). Some cold water is put into the cup A, and allowed to flow through the channel D, whence it rises through a perforated diaphragm into a space above, in which rests the bulb of a thermometer; the space itself being rendered water-tight by a thin cover of blackened glass, E. On turning the tap B, the water flows through the chamber, and so cools the glass cover down until a thin film of dew or moisture is deposited on it from the contiguous air; the precise temperature of this dew-point, or moment of dew, being deposited on the black glass is read off on the thermometer C, and recorded as that of the dew-point.

Another instrument, known as Daniel's hygrometer (Fig. 89), consists of a bent tube with a globe at each end, and is partly

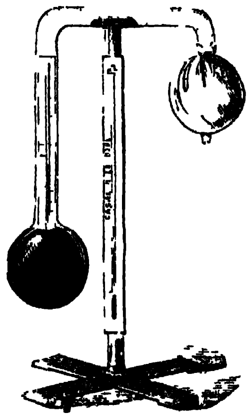


FIG. 89.—Daniel's hygrometer.

filled with ether, the rest of the space in the tube being filled with the ether vapour, all the air having been expelled. One globe is made of blackened glass, and contains a thermometer, while the other is covered with muslin. Before using the instrument, the ether is made to pass into the blackened globe containing the thermometer, while the muslin surrounding the second globe is moistened with ether. This ether rapidly evaporates, causing a condensation of some of the ether vapour inside the tube; this in its turn produces an evaporation of the ether in the blackened bulb. Now, whenever evaporation occurs, there is absorption of heat, so that the black bulb gradually becomes colder and colder, and the moment is soon reached when the air in contact with it

begins to deposit dew on its surface. So soon as this happens, the temperature shown by the contained thermometer is read off and recorded as the dew-point.

The most common form of hygrometer now employed in this country is that known as the dry-and-wet bulb thermometer (Fig. 90). It really consists of two ordinary thermometers mounted on a frame side by side. One of these has its bulb covered with muslin, and kept constantly moist by being connected with a small vessel containing distilled water, by means of the capillary action of a piece of cotton wick, which has been previously well freed from grease by being boiled in ether. The dry bulb gives, of course, the temperature of the air, while the wet one, in consequence of the evaporation constantly going on from its surface, gives a lower reading. The difference between the two temperatures recorded indicates the rapidity with which evaporation is proceeding, and, moreover, since evaporation is faster the drier the air, the indication of the degree of evaporation is a measure of the dryness or moistness (otherwise humidity of the air). If the air be saturated with moisture, of course no evaporation is going on, and the two thermometers will record the same temperature. In frosty weather, frequently the muslin covering and the water in the vessel will freeze, with the result that evaporation will not take place. In such case it suffices to brush the frozen muslin over with a brush dipped in cold water and allow this to freeze; at such time evaporation will be going on from the ice surface, so that it will be equivalent to its having a damp but unfrozen bulb.

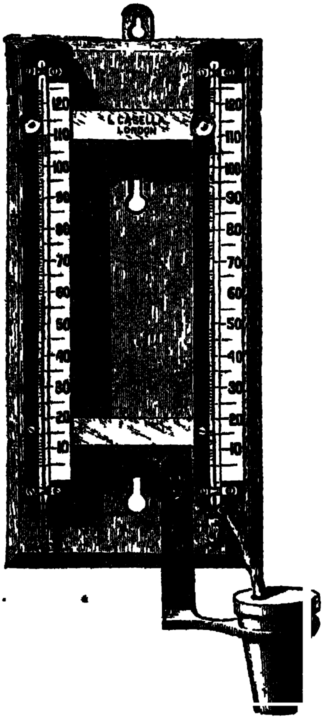


FIG. 90.—Mason's hygrometer, or the dry and wet bulb thermometer.

The calculation of the dew-point from the readings of the dry and wet bulbs can be roughly made by taking it to be as much below the wet-bulb reading as that is itself below the dry; but for greater accuracy use must be made of certain factors which

have been worked out by Glaisher, and given in the following table :—

Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.
10°	8·78	33	3·01	56°	1·94	79°	1·69
11	8·78	34°	2·77	57	1·92	80°	1·68
12°	8·78	35°	2·60	58°	1·90	81°	1·68
13°	8·77	36°	2·50	59°	1·89	82°	1·67
14°	8·76	37°	2·42	60°	1·88	83°	1·67
15°	8·75	38°	2·36	61°	1·87	84°	1·66
16°	8·70	39°	2·32	62°	1·86	85°	1·65
17°	8·62	40°	2·29	63°	1·85	86°	1·65
18°	8·50	41°	2·26	64°	1·83	87°	1·64
19°	8·34	42°	2·23	65°	1·82	88°	1·64
20°	8·14	43	2·20	66°	1·81	89°	1·63
21°	7·88	44	2·18	67	1·80	90	1·63
22°	7·60	45	2·16	68	1·79	91	1·62
23°	7·28	46	2·14	69	1·78	92	1·62
24	6·92	47	2·12	70°	1·77	93°	1·61
25°	6·53	48	2·10	71	1·76	94°	1·60
26	6·08	49°	2·08	72	1·75	95°	1·60
27°	5·61	50	2·06	73	1·74	96	1·59
28	5·12	51°	2·04	74°	1·73	97°	1·59
29°	4·63	52°	2·02	75°	1·72	98°	1·58
30	4·15	53	2·00	76°	1·71	99°	1·58
31	3·60	54°	1·98	77°	1·70	100°	1·57
32°	3·32	55°	1·96	78°	1·69		

To use the table, the rule is to multiply the difference between the readings of the two bulbs by the factor corresponding to the reading of the dry bulb, and subtract the product from the dry bulb; the result is the temperature of the dew-point. Thus, say the dry bulb is 62°, and the wet bulb is 56°; their difference is 6, and this, multiplied by the factor 1·86, or that corresponding to the dry-bulb reading, gives 11·16, and this, taken from 62°, yields 50°·84 as the temperature of the dew-point.

Having obtained the temperature of the dew-point, the *relative humidity* is determined by further reference to a table, like the following, in which the weight of a cubic foot of vapour, constituting saturation, at various temperatures is given :—

Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.
0	0·55	26°	1·68	51°	4·24	76°	9·69
1°	0·57	27°	1·75	52°	4·39	77	9·99
2°	0·59	28°	1·82	53°	4·55	78°	10·31
3°	0·62	29°	1·89	54	4·71	79°	10·64
4°	0·65	30°	1·97	55°	4·87	80	10·98
5°	0·68	31	2·05	56°	5·04	81°	11·32
6°	0·71	32°	2·13	57°	5·21	82°	11·67
7°	0·74	33°	2·21	58°	5·39	83°	12·03
8°	0·77	34°	2·30	59°	5·58	84°	12·40
9°	0·80	35°	2·39	60°	5·77	85	12·78
10°	0·84	36°	2·48	61	5·97	86	13·17
11°	0·88	37°	2·57	62°	6·17	87°	13·57
12°	0·92	38°	2·66	63°	6·38	88°	13·98
13°	0·96	39°	2·76	64°	6·59	89°	14·41
14°	1·00	40	2·86	65°	6·81	90	14·85
15	1·04	41°	2·97	66°	7·04	91	15·29
16°	1·09	42	3·08	67°	7·27	92°	15·74
17°	1·14	43	3·20	68°	7·51	93°	16·21
18°	1·19	44	3·32	69°	7·76	94°	16·69
19°	1·24	45°	3·44	70°	8·01	95°	17·18
20°	1·30	46	3·56	71°	8·27	96°	17·68
21°	1·36	47°	3·69	72°	8·54	97°	18·20
22°	1·42	48°	3·82	73	8·82	98°	18·73
23°	1·48	49°	3·96	74°	9·10	99°	19·28
24°	1·54	50	4·10	75°	9·39	100°	19·84
25°	1·61						

It is usual to express saturation by 100, and to calculate the relative humidity or the ratio of the absolute humidity to saturation by dividing the weight of a cubic foot of vapour corresponding to the temperature of the dew-point by that corresponding to the temperature of the air, and multiplying by 100. Thus, taking the same example as given above, in which the dry bulb reads 62°, the wet 56°, and the dew-point is found to be 50°·84, and using the foregoing table, we get the weight of moist vapour per cubic foot corresponding to the dew-point to be 4·21 grs., and this divided by 6·17, or the corresponding vapour weight for the air temperature, gives 0·68, and that multiplied by 100 shows the relative or percentage humidity to be 68.

This percentage saturation of the air is practically an inverse measure of the drying power of the air, and as such has a most important bearing upon climatic conditions, more particularly the degree of radiation from the earth's surface. We are all familiar with the peculiarly unpleasant effects of a hot moist atmosphere,

and with the invigorating influence of dry and crisp air. A saturated atmosphere at from 35° to 50° F. will be found to be intolerably chilly, and although the evaporation may be checked, and this source of heat-loss removed, yet the conduction and radiation due to the vapour in the air will be enormous. A temperature of 50° to 65° F. in a nearly saturated atmosphere seems to be not uncomfortable, as under those conditions an equilibrium seems to be established between the cooling action by conduction and radiation, due to the vapour in the air, and the supply of heat from checked skin evaporation. A saturated atmosphere with a temperature of from 65° to 80° F. becomes oppressive and sultry. Above 80° F., a saturated air becomes most oppressive, and it is doubtful whether life could be long sustained in a saturated atmosphere of 90° to 100° F., as the surplus heat cannot be removed by conduction or radiation, while at the same time the natural effort of the system to produce evaporation is enormously exaggerated. Humidity of the air is very generally supposed to be associated with the spread, or rather prevalence of disease; much moisture in the air certainly favours the continuance of colds, but at the same time appears to relieve bronchitis by assisting expectoration and the general discharge of mucus. Malarial diseases are said never to attain their worst form except the air be saturated with moisture, but on this point the evidence is not very strong.

Evaporation.—How much water is returned to the atmosphere by evaporation from any moist surface, such as that of the earth, is a factor which largely affects climate, but our knowledge regarding it is small, as it is both complicated and regulated by the temperature, and the degree of moisture in the air and winds. In this country, the mean annual evaporation from a square inch of water surface has been calculated to be about 20 inches. Various attempts have been made from time to time to measure the evaporation going on. An approximate idea of its amount can be obtained by exposing a measured volume of water in an open vessel of known area, and deducting from its final volume, after exposure for a given period, the amount of rain which has been known to fall into it during that time.

Winds.—The facts relating to winds are practically limited to those connected with direction, force or pressure, and velocity. As a rule, there is comparatively little trouble in obtaining records as to direction, as, if no vane is convenient, the smoke from a chimney will readily give the information, provided, of course, the observer has a precise idea as to where lies his north or south. A wind vane should be placed perfectly clear of trees, buildings, or anything likely to deflect the course of the wind, and, too, should be kept clean, and oiled to avoid sticking. All wind observations

should be recorded to the nearest point of the compass. To calculate the mean direction, it is usual to give an arbitrary numerical value to each observation, and then to analyze them. Thus, suppose we read to 16 points of the compass, and give a numerical value of 4 to each observation; if the wind be due N., we should give to N. the full value of 4; if the reading were N.W., we should give half the value of the observation, or 2, to N., and

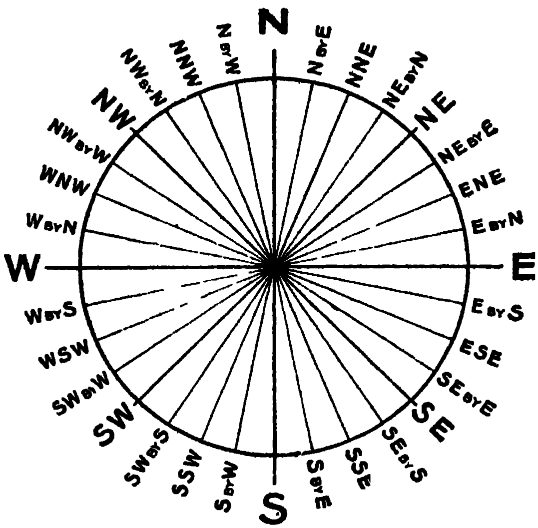


FIG. 97.—Points of the compass.

the other half to W. If the reading were N.N.W., then N. would get 3, and W. get 1, as their shares of the numerical value of the observation. Suppose we have the following observations of wind direction recorded: S., S.E., E., S.S.E., N.W., W.N.W., N.E., E.N.E., N., N.E. The calculation of the mean direction is done in the following way. Giving to each observation a numerical value of 4, we get—

	N.	S.	E	W
S. =	—	4	—	—
S.E. =	—	2	2	—
E. =	—	—	4	—
S.S.E. =	—	3	1	—
N.W. =	2	—	—	2
W.N.W. =	1	—	—	3
N.E. =	2	—	2	—
E.N.E. =	1	—	3	—
N. =	4	—	—	—
N.E. =	2	—	2	—
	12	9	14	5

Then, deducting the opposite directions from each other, we get—

N.	12		E.	14
S.	9		W.	5
Nett N.	3		Nett E.	9

That is, the mean direction lies in the N.E. quarter of the compass, and 9 *minus* 3 or 6 points nearer E. than N. Since each quarter consists of 90°, and each point on the compass equals $\frac{90}{8}$ or $11^\circ{\cdot}25$, the precise mean direction of the wind for these ten readings is six times $11^\circ{\cdot}25$ or $\frac{3}{4}$ of 90° from N. in favour of E., or at an angle of $67^\circ{\cdot}5$ from N., which on the compass is a mean direction of E.N.E.

The instruments for the measurement of wind, either as regards its force or pressure and velocity, are called *anemometers*. The earlier forms of these instruments were rectangular plates, whose movements, resisted by either springs or weights, recorded upon a chart by means of a connected pencil the amount of their displacement. In another form, the pressure of the wind is measured by making it blow into the mouth of an open tube kept facing the current by a vane, and noting the influence of the pressure exerted upon a column of water or mercury in a siphon. The later anemometers in use are those known as Robinson's (Fig. 92), consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis,

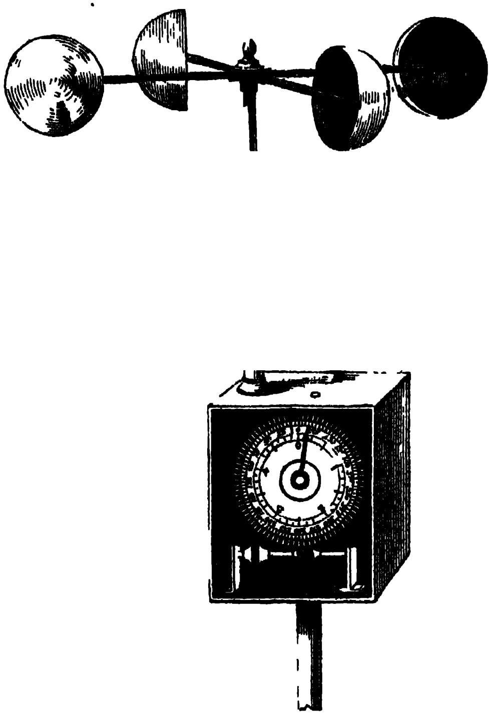


FIG. 92.—Robinson's anemometer.

which, by means of an endless screw, causes movements to be recorded upon a series of dials in terms of miles and parts of a mile. These instruments are graduated on the principle that, allowing for friction, the cups revolve three times slower than the wind moves; so that if the centres of the cups be 1·12 feet apart, each revolution corresponds to 3·52 feet of movement, or 10·56 feet of actual wind motion, and that 500 rotations of the cups indicate 1 mile of wind. Owing, however, to the allowance for friction being placed probably too high, and the cup motion being nearer 2 than 3 times slower than the wind, the velocity of wind movement as recorded by many instruments in general use is something like 20 per cent. too high. All anemometers to be reliable need to be kept scrupulously clean, well oiled, and placed in a thoroughly open position some 20 feet from the ground.

Various proposals have been made for estimating and describing roughly the force of the wind. The earliest was that of Admiral Beaufort, who, in 1806, devised a scale having a relation to the pressure of the wind upon the sails of a ship, and the amount of canvas which she could carry. This is given in the following table, slightly modified, from Scott's *Instructions in the Use of Meteorological Instruments* —

Beaufort scale	Description of wind.	Velocity in miles per hour.
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

Attempts have been made to express the wind's force as a pressure of so many pounds to the square foot., From experiments with various kinds of anemometers, Dines calculates the pressure P of the wind in pounds per square foot from the recorded velocity in miles per hour, on the assumption that the pressure equals one two hundredth ($\frac{1}{200}$) of the square of the velocity, or $P = 0·005 \times V^2$. According to this formula, a wind blowing with a velocity of 50 miles an hour exercises a pressure of $12\frac{1}{2}$ lbs. on the square foot.

In England, the wind has an average velocity of 8 miles an hour, and rarely exceeds 40. As a rule, at midday the wind blows

from sea to land, and from plains to hills, while in the evening the direction will be reversed. In this country, the most prevalent wind throughout the year is the S.W., the next is the W. The N.E. wind is the least prevalent, next the S.E., the E., and the N. The W. and S.W. winds are largely the result of the Gulf Stream, and are both warm and moist, while the E. and N.E. winds which blow from the cold areas of northern Europe and Asia are dry and cold. In all parts of the world there are periodical and variable winds due to local causes, while the permanent winds like the N.E. and S.E. trades take their direction from the rotation of the earth, and are caused by the constant movement of cold air from the poles towards the equator to replace the heated air of the tropics. The trade winds vary their prevalence over any particular area according to the season; but some other winds, such as the S.W. and N.E. monsoons of India, are essentially seasonal: The former is a wet wind, while the latter is in the main dry. The S.W. monsoon, usually commencing in May, is caused by the surface of the whole continent of India getting hotter than the sea, by which its air is rarefied, and rises to be replaced by comparatively cooler air currents laden with moisture blowing in from the Indian Ocean. The monsoon having exhausted itself by the time it reaches the northern limits of India, reverse currents of air begin to form, so that about October the wind blows southward from the N.E., and continues to do so until the same phenomena are started again in the early summer by the increased heat of the land. Among other seasonal winds may be mentioned the hot dry Khamsan wind of Egypt which blows from the desert during the spring; while in the Mediterranean, the Bora and Mistral are two cold dry winds coming from some portion of the Alps, the one being a N.E. wind affecting chiefly the Adriatic, and the other a N.W. wind blowing powerfully over southern France. On the other hand, the E. or S.E. winds in the Mediterranean, commonly called the Sirocco, are hot, moist, relaxing, and proportionately unpleasant.

Clouds.—Although at present all attempts to estimate the amounts of cloud are unsatisfactory, still continuous efforts are being made to record their extent and conformations. As the outcome of an International Meteorological Conference, held at Munich in 1891, it is now usual to divide clouds into five large groups, namely: (A) clouds existing very high in the air; (B) clouds at a medium height; (C) clouds lying low or near the earth; (D) clouds in ascending currents of air; (E) masses of vapour changing in form. A cloud is nothing more than the condensation of vapour into visible shape, and may occur in either of two ways. Either a layer of the atmosphere is cooled in bulk to near

its dew-point, with the result that a stratified mass of cloud of greater or less extent is formed, as the so-called *stratus*, or a body of moist air is intruded into a mass which is cold and dry, resulting in a cloud of a heaped-up or *cumulus* form.

A close analysis of the various shapes or kinds of clouds has resulted in their being divided into four principal forms, namely, the stratus, the cumulus, the cirrus, and the nimbus, while from these principal shapes result various modifications.

The *stratus* cloud can be best described as a widely extended but continuous horizontal sheet of vapour, very often forming at sunset.

The *cumulus* cloud is often very like a mountain in appearance, rising from a horizontal base; they are familiar to most people as conical heaps having often a bright or silver lining on the aspect towards the sun. The vapour in cumulus clouds is usually in the form of snow, and at its greatest density.

The *cirrus* cloud is best compared to a series of thin filaments not unlike a brush. It is the loftiest of all kinds of cloud, familiar examples being the so-called mares' tails, or parallel and diverging strips extending in any direction. Cirrus clouds are probably composed of ice or vapour in its least stage of density.

The *nimbus* is the true rain-cloud, being usually a horizontal sheet, having cumulus beneath and laterally, and with rain actually falling from it. Besides these four chief forms, there are compound modifications of them, the names of which are sufficiently descriptive. The following list will show the general distribution of clouds according to height; those marked with * usually accompany fine weather, while those with ** are characteristic of bad weather :—

A. Usually lying at a height of 16,000 yards in the air : Cirrus.* Cirro-stratus.** Cirro-cumulus.

B. Commonly from 3000 to 6000 yards high in the air : Cirro-cumulus.* Cirro-stratus.**

C. Those having their bases from 1000 to 2000 yards high in the air : Strato-cumulus.* Nimbus.**

D. Those in ascending columns of air, their bases being as low as 1400 yards, and their summits from 3000 to 5000 yards in the air : Cumulus.* Cumulo-nimbus.**

E. Masses of vapour in transition shapes like fogbanks—up to 1500 yards : Stratus.

Halos and Coronæ are circles which appear round the sun and moon. Halos arise from the existence of minute prisms of ice in the atmosphere, and consist of refracted light; they usually

portend unsettled weather in these latitudes. Coronæ are more common than halos; they arise from the interference of rays of light passing through a mass of minute globules of water, and accordingly are seen whenever light clouds pass between us and the moon.

Atmospheric Pressure.—It has already been explained that the density or pressure which the atmosphere exerts is determined or noted by means of instruments called barometers. These are usually either mercurial, glycerin, water, or aneroid barometers. As commonly constructed, the mercurial barometer consists of a tube of glass about 36 inches long, closed at one end, filled with mercury, and placed vertically with the open end dipping into a cup containing mercury, called the cistern. When discussing the question of the weight of air, the principle of the construction of this instrument was explained, as also was the fact that the difference between the heights of the two mercurial surfaces exactly measured the atmospheric pressure. This in terms of mercury at sea-level, in this country, is 29·92 inches. As the mercury in the tube balances, as it were, the pressure of the air, it is obvious that it falls with a lessened pressure, but rises with an increased pressure, so that if by means of a fixed scale we note the precise length of the mercury column, we may measure the weight of the atmosphere. Such a scale is commonly divided into inches or other measures of length. In some common forms of barometer, this scale is laid off from a zero at some fixed point in the cistern, with the result that, except at one particular point, the instrument reads wrongly, because during the changes which take place in the length of the column, the level of the mercury in the cistern also changes, being sometimes higher and sometimes lower than the fixed zero point. In order to overcome this difficulty and source of error, various expedients have been resorted to, so as to compensate for the ever-changing level of the mercury in the cistern; thus, (1) by a so-called capacity correction which, duly noted and recorded on the scale by the maker, states the ratio of the interior area of the tube to that of the cistern, thus capacity $\frac{1}{40}$. To apply this correction, there is always marked on the scale a certain height of the column which is correctly measured by the scale. This exact height is termed the *neutral point;* when the mercury sinks below this, the height read off will of course be too great, because the level of the mercury in the cistern will have risen above the zero in a proportionate amount; for the same reason, when the mercury rises above the neutral point, the reading will be too small because the level of the mercury in the cistern will have fallen below the zero of the scale. The capacity correction is

applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. Thus, suppose in the case of a barometer marked with a neutral point, and with a capacity correction of $\frac{1}{50}$, the mercury stands 1 inch above the neutral point, then $\frac{1}{50}$ of the difference the height read off and the neutral point, or, in this case, $\frac{1}{50}$, or 0·02 inch, must be added to the observed reading. (2) In the Kew barometers the error is obviated by graduating the scale in nominal inches, which are shorter than true inches, from above downwards in proportion to the relative size of the diameter of the tube and cistern. (3) Another device is to do away with the cistern altogether, and employ a U-shaped tube, in which one arm is shorter than another and open at one end. Both levels are read upon a scale, and the reading of the barometer is the difference in level of the mercury in the two legs. These are sometimes called siphon barometers, of which the ordinary wheel barometer is a common type; in this latter instrument the movements of the mercury are transmitted from a float on the mercury in the open tube, by means of a string, to an axis which carries an index moving over a dial-plate as in a clock. (4) In what are called the Fortin barometers, or best standard barometers, the necessity for capacity correction, or either of the other above-named devices, is avoided by giving the cistern a pliable base of leather, and capable of being raised or lowered by means of a screw *c* (Fig. 93). The upper part of the cistern is made of glass, through which the zero of the scale can be seen as a piece of ivory, whose lower extremity is called the *fiducial point*, *d*. Before taking a reading, the level of the mercury in the cistern must be set exactly to this point, by raising or lowering the cistern base by means of the screw; since the fiducial point is the tip of the piece of ivory, and accurately corresponds, as a fixed point, to the zero of the scale, after the level of the mercury in the cistern has once been carefully adjusted to it, it is obvious that the height of the column of mercury then read will be an accurate measure of the atmospheric pressure.

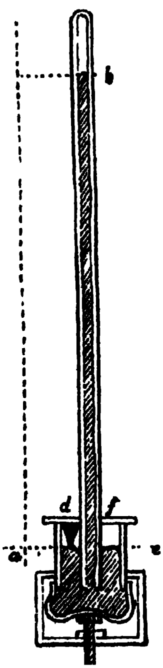


FIG. 93. — Diagram showing cistern of a Fortin's barometer.

In order to secure a greater exactness in the reading of a barometer, use is made of a secondary scale, or vernier, which slides

upon the principal scale. In all standard barometers this vernier scale is so graduated that 25 of its divisions correspond to 24 of those upon the other, or fixed scale. Consequently, each space or division on the scale is $\frac{1}{25}$ of its own size larger than each space on the vernier, and as each such space on the scale is $\frac{1}{20}$, or of $\frac{5}{100}$ an inch, therefore the vernier exhibits differences of $\frac{1}{25}$ of $\frac{1}{20}$ inch, or $\frac{1}{500}$, or 0·002 inch. In taking a reading of a barometer, the first thing to do is to note the temperature of the instrument by means of the usually attached thermometer; next, adjust the mercury in the cistern to the fiducial point, if it be one made on Fortin's principle; then place the vernier so that its lowest edge is level with the top of the mercurial column. If this level coincide exactly with one of the principal scale-divisions, there is no need to use the vernier; but if it do not so coincide, the use of the vernier will accurately measure the excess of the mercury-level over the next lowest division or mark on the scale. To do this, we must follow the vernier scale up, until we find one of its marks exactly corresponds with one on the fixed scale; call it x, and, as each of these represents $\frac{1}{500}$, or 0·002 inch, we have $x \times 0{\cdot}002$ inch as the exact distance which the mercury column is over and above the next lowest mark to it on the principal scale. Thus, in Fig. 94, presuming that the lower edge of the vernier, A B, has been accurately adjusted to the level of the top of the mercurial column, we find that that corresponds to a point just below 29·20 inches, and something above 29·15 inches; that is to say, neither of those readings gives the absolutely correct height of the mercury. Following up the vernier, we find that its seventeenth line or mark is the first to exactly coincide with one on the principal scale CD; therefore, if we read that as meaning $\frac{17}{500}$ of an inch, or 0·034 inch, or the exact amount by which the top of the mercury column exceeds 29·15 on the fixed scale, we get by the addition of these two numbers 29·184 inches, as the correct reading of this particular example.

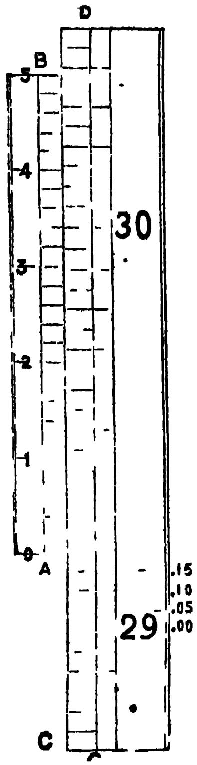


FIG. 94.—Vernier attached to a barometer scale.

The reading having been thus accurately taken, it remains to apply certain corrections; these are (1) index error, (2) for capillarity, (3) for temperature, (4) for height above sea-level.

The first two corrections have to do with the actual instrument, and are usually very small and determined before the instrument is sent out, and their amounts duly entered on the certificate which accompanies the barometer. The error due to temperature is one which affects, not only the mercury, but also the brass of the scale, and in extremes of heat or cold may be considerable; this explains why it is so important to note the temperature before taking the reading. To secure uniformity of barometric records all nations have agreed to reduce their barometer readings to what they would have been had both the mercury and brass scale been at 32° F., or 0° C. All good barometers are made with brass scales, and for these the necessary temperature corrections are given in the following table:—

Temp	27 inches	28 inches	29 inches	30 inches	31 inches
30°	−0·004	−0·004	−0·004	−0·004	−0·004
40°	−0·028	−0·029	−0·030	−0·031	−0·032
50°	−0·052	−0·054	−0·056	−0·058	−0·060
60°	−0·076	−0·079	−0·082	−0·085	−0·087
70°	−0·100	−0·104	−0·108	−0·111	−0·115
80°	−0·124	−0·129	−0·133	−0·138	−0·143
90°	−0·148	−0·153	−0·159	−0·164	−0·170
100°	−0·172	−0·178	−0·184	−0·191	−0·197

Corrections for height above sea-level are usually made by reducing all readings to sea-level, which is the level of the mean half-tide at Liverpool. If we know the exact height of the particular spot above or below sea-level, the necessary correction is commonly obtained from specially prepared tables; but the application of this correction is very little needed in everyday life, unless records are made for scientific purposes. As an approximate calculation the correction may be said to be about 1 inch for every 1000 feet.

Although in the majority of barometers the atmospheric pressure is measured by a column of mercury because of its high specific gravity, still, in some others, other liquids are employed, such as glycerin, which, having a lower specific gravity, is much more sensitive to variations in pressure. The specific gravity or density of mercury is 13·59, while that of glycerin is but 1·26; the atmosphere we know can support a mercurial column 29·92 inches high; therefore, it can equally support a glycerin column 27 feet high: or, in other words, a fall of 1 inch in a mercurial column is the equivalent of a fall of 10·7 inches in a glycerin instrument—the latter, in consequence of

its greater range, being far more sensitive as an indicator. Water barometers have also been made, in which the column required to balance the atmosphere is 34 feet. Besides mercurial, glycerin, and water barometers, familiar instruments in general use are aneroid barometers—their principle is very simple. They are small, air-tight metallic boxes, exhausted of air inside, and so constructed that as the atmospheric pressure rises so the metal box is forced in, and, helped by means of a strong spring, bulges out again when the pressure lessens. The movements of the metal are, by a suitable arrangement of levers, made to turn an index on a dial face (Fig. 95). The dial is of course graduated by comparison with a standard mercurial

FIG. 95.—Aneroid barometer.

instrument. Aneroids are very sensitive and convenient, but liable at times to go hopelessly wrong, on which account they need to be periodically checked against a standard mercurial instrument. Mercurial barometers may be said to measure *absolute* pressure, while aneroids measure *relative* pressure.

By a combination of a series of aneroid vacuum boxes, the movements of which by means of a lever are multiplied, and recorded upon a revolving cylinder, so-called recording barometers have been made, and for observatory work these instruments serve a useful purpose, but, of course, are not absolutely accurate without being constantly checked against standard mercurial instruments.

Barometers generally, and aneroids in particular, have been of the greatest value as measurers of the height of any given place

above the sea-level; the barometer, of course, falls when heights are ascended, but the diminution of pressure is not uniform. Strictly speaking, such observations involve calculations of more or less complexity, but, for rough work, fairly accurate results can be obtained by simple rules. It is, however, necessary to make three readings of the barometer. Suppose it is required to know how much higher a town, A, is above a source of good water-supply situated at B. Read the barometer at A, go then to B and read it there, then back to A and read it there again; take a mean of the two readings at A, and determine the difference between it and the reading at B; this, multiplied by 9, and neglecting decimals, will give the difference in height between the two places in feet. Thus, suppose the first reading at A had

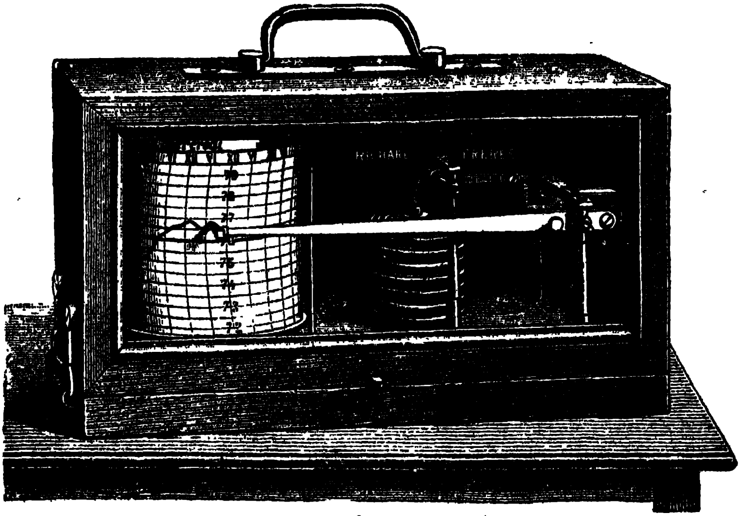


FIG. 96.—Self-recording aneroid barometer.

been 29·94, and the second had been 29·90, the mean, of course, would be 29·92; and suppose the reading at B to have been 30·35, the difference between these two is 0·43, which, multiplied by 9 and ignoring decimals, gives 387 feet as the height of A above B. When the barometer at the higher station is below 26 inches, or the temperature above 70° F., the multiplying factor should be 10. The results by this method are correct to about 5 feet in 100.

Results correct to about 1 foot in 100 can be obtained by (1) estimating the mean temperature of the air; (2) ascertaining the mean barometric pressure; (3) using, instead of the factors 9 or

10, the figures in the following table, which correspond most nearly to the values obtained for (1) and (2) :—

	Mean temperature (Fahr.).				
	30°	40°	50°	60°	70°
Mean pressure, 27 inches .	9·7	9·9	10·1	10·3	10·6
" " 28 " .	9·3	9·5	9·8	10·0	10·2
" " 29 " .	9·0	9·2	9·4	9·6	9·8
" " 30 " .	8·7	8·9	9·1	9·3	9·5

Example—

Temperature at Lower Station = 60 Pressure at Lower Station = 30·25
" " Upper " = 56° " " Upper " = 29·02
Mean temperature = 58 Mean pressure = 29·63

Pressure at Lower Station = 30·25
" " Upper " = 29·02

Difference = 1·23
Multiplier = 9·3
Altitude = 123 × 9·3 = 1143·9 feet.

In most parts of the world there are distinct periodical and non-periodical changes in the atmospheric pressure as indicated by the barometer, but in these islands the former are barely noticeable owing to the intensity of the non-periodical changes. In reality the periodic changes are in the form of two maxima, namely, at about 9 a.m. and 9 p.m., with two minima at 3 a.m. and 3 p.m. In this part of the world the range between these two is not more than 0·02 inch, but in the tropics it amounts to quite 0·1 inch. The annual variation of pressure in this country is most variable, but the maximum readings are usually about the end of May or early in June, while the minima are at the end of October or early in November.

Unless very extreme, variations in atmospheric pressure appear to have only an indirect influence upon health; but when the barometric pressure is lessened to the extent of some inches, as in mountain climbing and balloon voyages, or much increased, as in diving-bells, or pneumatic tubes and chambers used in pier-driving below water, marked effects are produced upon both the breathing and blood circulation of men. Under very low pressures, the pulse rate and respirations are at first increased, becoming afterwards gradually slower and stronger. After some lengthened exposure to low atmospheric pressure, the thorax and lungs become widened with deep respiration. The general results of

prolonged residence under low atmospheric pressure are good. The thinning, as it were, of the atmosphere and the lessened amount of oxygen available stimulates a development of the inspiratory act and a more vigorous vascular system. These effects are well seen in the broad and deep chests with well-developed muscles of all mountain races. The effects of increased atmospheric pressure are more marked, as evidenced by the deafness, ear pains, and sense of tightness round the head which are experienced by those going down in diving-bells. In pneumatic chambers and tubes used for pier-driving and laying the foundations of bridges, the pressure in the air-chambers is usually of from 3 to 4 atmospheres, and if due precautions are taken to neither increase nor lower the pressure too rapidly, no symptoms or inconvenience are experienced by workmen when employed in them for hours together. What accidents and ill effects have occurred are chiefly in the form of prickings, muscular pains, nose bleedings, and paralysis, and these have occurred commonly after leaving the high-pressure chambers or tubes, and when the reduction of pressure has been too rapid. Very few unfavourable effects appear to occur under the actual high pressure. The great danger in all these cases appears to be in the too sudden reduction of pressure. If time be given, the body seems to be quite able to accommodate itself to the extreme variations of pressure: thus in a balloon ascent made by Glaisher and Coxwell, these observers were able to withstand as low a pressure as indicated by 8 inches of mercury: while, on the other hand, men who worked in sinking piers for the Forth Bridge did so in air-chambers in which the barometer stood as high as 72 inches. These two instances give a range of atmospheric pressure extending over 64 inches, supportable by man.

In everyday life, the variations of barometric pressure, though rarely extending over a greater range than 3 inches, have a practical value as indicating the general character of the weather and the probable presence or absence of rain. It has already been explained how rain is dependent upon the presence of moisture in the air, and upon how well the air can retain that moisture. It has, too, been explained that when dry air receives moisture its volume increases, with the result that an amount of air which, when dry, measures 1 cubic foot, and weighs, at 50° F., 546·8 grs., becomes, when saturated with watery vapour at the same temperature, 1·1021 cubic feet, with a weight of 550·9 grs.; so that 1 cubic foot of the saturated air weighs but 544·3, or 2·3 grs. lighter than it did when dry. It is this physical fact of moist air weighing lighter than dry air that causes the barometer to fall in consequence of lessened atmospheric weight when much

moisture is present, and, consequently, rain imminent. It must, however, be remembered that other causes than moisture will often affect the barometer, notably wind, though, in the main, its movements are dependent largely upon the presence or absence of watery vapour in the air. It was the early recognition of this fact that led to the use of the barometer as a weather-indicator. In former years the value of the barometric reading was necessarily limited to the particular spot at which it was noted; but recently, as the result of increased facilities of communication between one place and another, it is possible to obtain simultaneous readings of the barometer at any given time at several spots distributed over a wide area. Now, if these are recorded on a map, and lines be drawn between and connecting all places where the same pressure prevails, we obtain what is called a *synoptic chart*, made up of lines of equal barometric reading, or *isobars*, as they are termed. This is what is actually done in all the chief meteorological stations, and experience has shown that these isobars commonly assume certain typical forms or shapes, which are again usually associated with certain kinds of weather. It is upon these data and facts that the modern methods of weather forecasting are based.

Isobars, or lines drawn on a chart indicating places of equal barometric pressure, are found to arrange themselves practically

FIG. 97.—Diagram showing the chief types of isobars.

into seven different shapes called cyclones, secondary cyclones, V-shaped depressions, anti-cyclones, wedges of high pressure, cols and straight isobars; the general characteristics of each are shown in Fig. 97. The closeness of the isobars one to another, or the rapidity of changes in pressure, constitute what is called the "barometric gradient," and just as we measure and express a railway gradient as being 1 in 20, 1 in 100, and so on, so can

we say that barometric gradients are so many thousandths of an inch in 15 miles, or so many millimetres in one degree of the meridian. The steepness of the barometric gradients directly governs the velocity of the wind over any particular place, the wind's velocity being greatest at the localities of steepest gradient, and *vice versâ*. In addition to this, if the wind's direction at each place be noted on a synoptic chart, it is found to be nearly parallel to the trend of the isobars, and tends to cross from the higher to the lower ones. This fact has found expression in what is known as Buys Ballot's law, namely, that if you stand with your back to the wind, the lowest pressure lies to your left and in front.

Cyclones.—An area of low pressure, and the whole system connected with it, is called a depression or cyclone, and in America "a low." As seen on a synoptic chart, cyclones are circles formed by concentric isobars, in which the outer lines mark a higher pressure than the inner ones; they constitute the most frequent arrangement of isobars in these latitudes (Fig. 98). They usually travel from west to east, at the rate of about 20 miles an hour, and are invariably associated with bad weather. From what has already been said, it is evident that the actual pressure or height of the barometer is of little moment; the forces involved are due to the gradients or differences of pressure, and are greater the steeper the gradients. Hence a cyclone may be of a mild type, or be a gale or hurricane, according as to whether the gradients are gentle or steep. If we analyze the weather associated with a cyclonic disturbance, we find that the foremost portion of a cyclone area is always marked by stratiform clouds, moist heavy atmosphere, and the usual signs of coming rain, such as a pale moon, watery sun, dirty gloomy sky. As the cyclone advances, a drizzling gradually changes into a driving rain, accompanied in the trough or situation of lowest pressure by squalls of wind. As the cyclone area shifts its position or moves onward, the rain moderates into showers, followed by a brighter sky with cumulus clouds and a sharp brisk feeling in the air. If we study the barometer changes at different points in the path of a cyclone, it is at once obvious that in the fore part of the area of depression the barometer is everywhere falling, while in the rear part it is everywhere rising, and the turning-point, or line of lowest pressure, is what is called the trough. A cyclone may be compared to a cup-shaped hollow, the isobars being simply contour lines. The extent or area of a cyclonic disturbance may vary from 10 or 20 to some thousands of miles, covering even the whole Atlantic or the greater part of Europe. Cyclones are usually oval and not circular in form, their longest diameter

being in these latitudes in a direction nearly W.S.W. to E.N.E. in the majority of cases. When the dimensions become great, especially if the system be much elongated, a cyclone frequently breaks up into two, three, or even more separate centres of depression. Large cyclones are, of course, much modified in both form and position by the variations of the deflecting force due to the rotation of the earth, and arising from difference of latitude. As a rule, the higher the latitude, the greater is the average size of cyclones. In the tropics, cyclones are usually smaller and circular. It is important, however, not to confound small cyclones with either waterspouts or tornadoes, which are too small to be much influenced by the rotation of the earth,

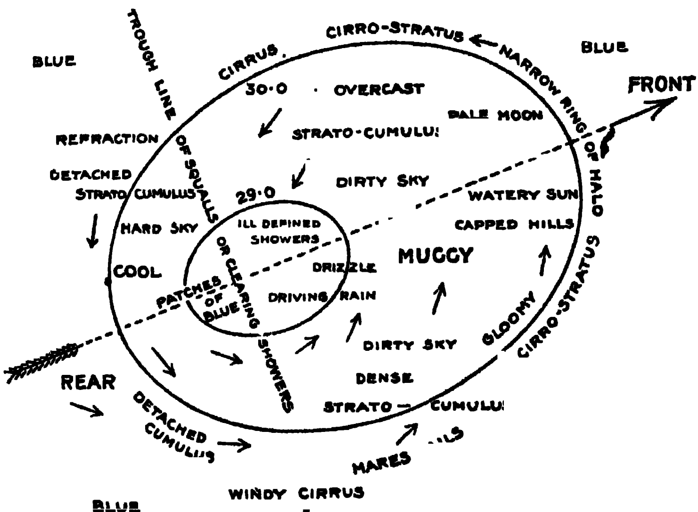


FIG. 98.- Diagram showing weather typical of a cyclone. (After Abercromby.)

besides which they are special phenomena of a distinct nature. The direction of the wind is, in all cyclones, obliquely across the isobars, and may be described as blowing spirally into the area of low pressure towards the centre, and from the central area in an upward direction. The particular angle at which the incurving of the wind takes place in a cyclone depends on the friction between the air-currents and the earth's surface, the angle being smaller the greater the friction. Thus, according to Ley, the angle between the direction of the wind and the isobars is 29° for coast stations, and 13° for inland stations, thus showing distinctly the increased effects of friction on land. It has already been stated that cyclones in these latitudes for the most part

move in an easterly direction; when a westward motion occurs, it is usually slow and seldom long-continued. The advance of a depression is commonly in a direction perpendicular to the line of steepest gradient, so that the highest pressure lies to the right; while also the temperature is highest to the right of its track. The rate of advance of a cyclone varies within very wide limits; on the whole, deep depressions move faster than shallow. The average rate of motion of translation of cyclones over Europe is from 20 to 30 miles an hour, while in America they travel commonly as rapidly as 50 miles an hour. So far as is known, cyclonic storms and weather seldom or never originate within five degrees of the equator, but this intermediate tropical belt is the scene of extremely violent hurricanes, which have a tendency to move in a westerly or north-westerly direction, and, moreover, appear to behave according to laws too complex to be given in detail here. The general weather characteristics of a northern cyclone area are given in Fig. 98, which shows such an arrangement of isobars shifting in a north-easterly direction.

Secondary Cyclones are areas of low pressure formed by looped or incompletely circular concentric isobars with the lowest pressure in the centre. They have many weather features in common with primary cyclones, moving like them mostly from west to east. They frequently follow primary cyclones, and their bad weather is usually associated with calm and stationary barometers

V-shaped Depressions are angular intervals or areas with the lowest pressure in the interior, and frequently form between adjoining anticyclones, and are, as it were, a specialized form of cyclone, or even may form part of a cyclone. They have been aptly described as tongues of depression projecting from a cyclone situated to one side; in the northern hemisphere the point or tip is usually towards the south. These V's commonly move from east to west, and the weather experienced by an observer over whom one of these areas of depression drifts is from blue sky to cloud, later on rain with a falling barometer and south-west wind, then a squall, during which the wind jumps round to north-west, followed by a rapidly clearing sky and a rising barometer. This type of isobars is always associated with squalls or thunderstorms, an historical instance being one of exceptional severity, which occurred on March 24, 1878, and which was the cause of the sinking of H.M.S. *Eurydice* off the Isle of Wight. Not only secondary cyclones but V-shaped depressions are in general most uncertain in their movements, and their occurrence is consequently very difficult to foretell. The extreme rapidity with which they travel at times, and the violence of the wind and rain developed within them, render them a source of great danger to both life

and property. The peculiar summer thunderstorms of Central Europe and America are nearly always associated with V-shaped depressions.

Anticyclones.—These are areas of high pressure formed by more or less circular isobars, with the highest pressure in the centre. They differ from all other arrangements of isobars in tending to remain stationary and, too, to extend over large areas. The air is calm and cold in the centre, while on the borders the wind blows round the centre spirally outwards in the direction of the hands of the clock; thus, on the east side the wind comes

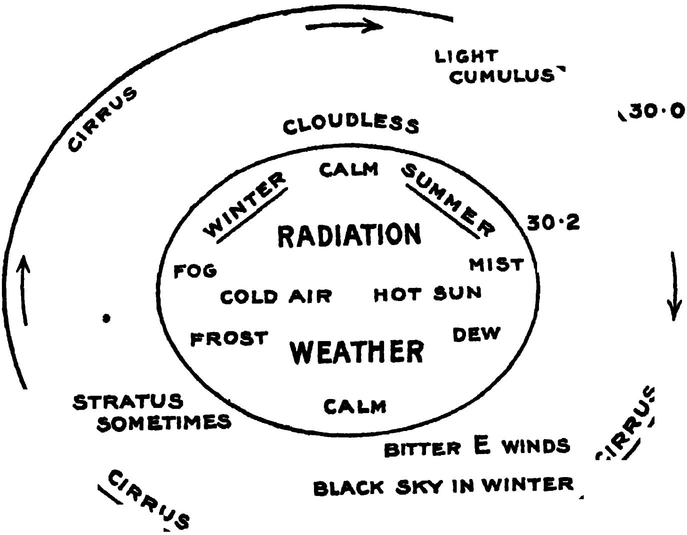


FIG. 99.—Diagram showing weather typical of an anticyclone (After Abercromby.)

from the north, on the south from the north-east, on the west from the south-east, and on the north from the west. In describing the cyclonic system it was explained how the wind in the centre of that system was an ascending current; that wind circulation is compensated by an equivalent descending current in what is in all respects the opposite of the cyclone, namely, the anticyclone. The characteristic circulation of the air in this is therefore exactly the reverse of that in a cyclone: it blows in the same direction as the hands of the clock, more spirally outwards from the centre at or near the surface of the earth, and inwards towards the centre at the level of the highest clouds. In

anticyclonic systems the barometric gradients are slight, and the normal wind circulation usually disturbed or disguised by accidental or local causes. The general weather features of an anticyclone are given in Fig. 99, from which it will be seen that they are the exact opposite of cyclonic conditions, being blue sky, dry cold air, a hot sun, little or no wind, and a hazy horizon—in fact, fine weather. The diagram shows in one half the summer characteristics of an anticyclone, in the other those of winter. Certain regions of the globe are remarkable for the existence of permanent and recurrent anticyclone systems. There is a permanent area of high pressure near latitude 30° north, called the Atlantic Anticyclone, which varies in extent from month to month, attaining its greatest intensity in summer and least in winter. Another permanent area is that over the large land surface of Asia and Eastern Europe in which the pressure is usually excessive during winter. It is the existence and more or less permanency of these two large areas of high pressure which combine to give a north-westerly gradient towards a stationary low-pressure centre near Iceland and to govern the motions of cyclones, which tend to skirt round their borders in an easterly direction. It is important to remember that, while an anticyclone system compensates a cyclone in the matter of transferring air from one level to another, there is no mutual relation between them in the sense of cause and effect.

Wedge-shaped Isobars usually point to the north and indicate areas of high pressure moving along between two adjacent cyclones. Though very usually associated with fine weather, it is only temporary because wedges of high pressure are never stationary, and are commonly followed by well-defined cyclonic areas. So far as weather is concerned, we may regard the two sides of the wedge as the rear and front of cyclones, and the wedge itself as a mere projecting tongue of an anticyclone. The wide end of the wedge is often associated with fog, and the narrow end with thunderstorms or showers.

Cols, or necks of comparatively low pressure, generally lie between two anticyclonic areas. Over them the weather is dull, gloomy, and stagnant, while in summer violent thunderstorms are frequently associated with them. Like the following, cols are essentially intermediate systems.

Straight Isobars are those without any curve, and may trend in any direction. This arrangement of isobars only marks the position of a barometric slope, and does not include any area of either high or low pressure. This form is essentially temporary and an intermediate arrangement of the atmospheric circulation or pressure which precedes the formation of a cyclone. The

weather associated with straight isobars is too transitional to be characteristic, but very frequently is that of a hard sky, with a blustering wind and an inclination to rain, such as one experiences as to remark that "when the wind falls it will rain."

What are known as squalls, or puffs of wind of varying intensity, appear to be caused by the sudden breaking of the cold dense upper layers of air through lower and warmer layers lying underneath, condensing the vapour in the latter and causing them to ascend. In contrast to them are the various kinds of squall attributable to the sudden ascent of masses of warm air; examples of this phenomenon we know, as the familiar dust whirls on a dry road, or the dust storms, waterspouts, and tornadoes of the tropics. As in the case of cyclones and anticyclones, the question, What is the cause of these descending and ascending air-currents? is one of some complexity, and has not yet received an adequate explanation.

It must not be forgotten that all the foregoing forms of isobars are at any time liable to break up, or at least pass into new forms, so that, although every part of every shape of isobars has a characteristic weather and sky appearance, still, owing to their often rapid breaking up, forecasting of weather is not always certain to come true. Cyclonic disturbances, for instance, are frequently diverted from their course by meeting a coast line or range of mountains, or even by the formation of areas of high pressure; so that their velocity is neither regular nor their direction of movement necessarily straight. On the other hand, experience shows that when advantage is taken of Transatlantic and other meteorological observations telegraphed to a central meteorological office, synoptic charts can be prepared of such magnitude and detail as to render weather forecasting comparatively successful in a great percentage of cases. All meteorological phenomena are practically the products or results of the circulation or motion of a moist atmosphere, and consequently forecasting weather is nothing more than saying how and where certain air-currents or eddies will move, or when new ones will form, and whether they will be gentle or violent. From the rapidity with which meteorological changes take place, the use of telegraphy is absolutely necessary if any success is to be attained in forecasting, and even this information can be only of use in some central office presided over by an experienced forecaster thoroughly conversant with the motions of low-pressure areas in his own country. It will be readily understood that in some countries forecasting is easier than in others. Thus, in the temperate zone, where most disturbances move from the west, those countries will be best suited for weather forecasting

which lie to the east of a well-observed land area. For this reason Norway and Germany are better placed for weather forecasting than either France or England. Large areas of land and water mainly determine the great areas of high and low pressure, hence Great Britain being placed where it is, on the boundary, so to speak, between anticyclonic and cyclonic systems, renders the prognostication of weather peculiarly difficult in these islands, more particularly as their geographical position precludes an early knowledge of cyclones forming over the Atlantic. Moreover, just as an outlying rock is exposed to the wash of every sea, so is England exposed to the disturbing influences of every type of European or Atlantic weather, and has, in consequence, more unsettled weather than any other part of Europe.

CHAPTER X.

VITAL STATISTICS.

PROBABLY no single cause has contributed more to the attention now paid to questions of public health than the careful collection of the statistics of births and deaths, and of the causes of death which have been collected and published by the Registrar-General's Office in England during the past fifty years. These collections of figures and facts are usually spoken of as vital or health statistics, because they are so intimately associated with the various problems relating to the health and chances of life which the community enjoys. So valuable has been the work done, that we are now able to determine with some precision the causes and limits of mortality, and by the study and analysis of the collection of facts known as vital statistics to apply them as tests of the health of the communities to which they refer.

The chief vital statistics, bearing upon public health, relate in detail to past and present facts concerning populations, age and sex distribution, births, marriages, deaths, diseases, duration of the hours of occupation and general social conditions, such as the health of each class of the community as judged of by the expectation of life at given ages. Statistics of sickness, apart from mortality, have as yet not been attempted, chiefly on account of the difficulty in collecting the data with accuracy.

Population.—The very first necessity is to know what is the

precise number of the people. Our knowledge upon this point in each place in Great Britain depends primarily upon the census returns which have been made regularly and with increasing care every ten years since 1801. It will be at once obvious that the facts relating to the numbers living of each sex and age periods and the numbers employed in certain callings can only be accurately known in actual census years, and making from them estimates for intermediate years. An interval of ten years between the takings of the census is now acknowledged to be too long, and it is probable that if our population statistics are to remain in any way accurate, more frequent enumerations of the people will need to be taken, and even then certain inaccuracies are sure to exist, due chiefly to the imperfect education of large numbers of householders and heads of families, these defects of information collected relating especially to occupations and ages. It is remarkable what a large number of people do not know their precise age, these persons generally giving their age in census returns in some multiple of ten. Another source of error and perplexity in all census returns is the too frequent wilful misstatements made by women, owing to their desire, for various reasons, to be thought between 20 and 25 years of age. This is shown by the fact that in each successive census, the number of women returning themselves as between 20 and 25 is larger than the number of girls returned in the census of ten years before as between 10 and 15 years of age. The former being only the survivors, after the lapse of ten years of these latter, they should of necessity be fewer in number. The male sex is not altogether free from blame in the same matter, though the bias goes in the opposite direction. Thus, men of the poorer classes, who have passed the age of 60, constantly overstate their age for the sake of certain definite advantages, such as getting outdoor relief, or, if entering the poor-house, gaining some special privileges not granted to their juniors. Some really old people often exaggerate their age in order to appear as centenarians.

In attempting to estimate the population of any given locality for any year intermediate between the collection of census returns. it is necessary to calculate the probable decrease or increase of the particular population by comparing the numbers of the latest enumerations. Thus, say a town had in 1891 a population of 35,626, and in 1901 one of 38,754, and it was required to know its estimated population in June, 1906: it is only fair in such a case to assume that the 1906 population will be greater than the 1901, and, if we further assume that the increase will be at the same rate as between 1891 and 1901, by taking the difference between the 1891 and the 1901 populations and dividing by ten,

we get the annual increase of population for that town. Inasmuch as the census is always taken in the first quarter of the year, and we require the population at the end of June, 1906, an interval of $5\frac{1}{4}$ years will have elapsed since the last census; if, therefore, we multiply the annual increase of population, which in this example is $\frac{38754 - 35626}{10} = 312{\cdot}8$, by $5{\cdot}25$, we get an increase of 1642 to be added to the 1901 population, giving an estimated population of 38,754 + 1642, or 40,396 for the middle of 1906.

The foregoing method of calculating an estimated population is fallacious, as it presumes the increase or decrease will be as in an arithmetical progression. The true law of population increase or its decrease is that of a geometrical progression, and is very suitably compared to the increase of a sum of money at compound interest. The increase in x years is derived from the increase in one year by multiplying 1 *plus* the annual rate of increase x times into itself. If the increase in one year be 1·5 per cent., 1 becomes 1·015 in one year, and 1·015 multiplied x times into itself will give the increase in x years. To obtain, therefore, the annual rate of increase in x years, the *xth root*, and not the *xth part* of the x rate of increase, must be taken. It is on this assumption, that the increase or decrease of a population proceeds as in a geometrical and not in an arithmetical progression, that the Registrar-General calculates the estimated populations for London and other large towns, as well as for the whole country, for intercensal years. On this basis the calculations are more conveniently performed by logarithms in the following manner:—

Taking the same example as above, we find the logarithm for the 1901 population, or log 38,754 = 4·5883165, and deduct from it the logarithm for the 1891 population, or log 35,626 = 4·5517671; this gives 0·0365494, which is the logarithm of the decennial increase. Dividing this by 10 gives us 0·0036545, or the logarithm of the annual increase, and a quarter of this is 0·0009136, or the logarithm of the quarterly increase. By adding together the logarithm of the 1901 population and five times the logarithm of the annual increase and the logarithm of the quarterly increase, we get the logarithm of the mid-year 1906 population, or 4·6075026, which, by reference to a set of tables, = a population of 40,504, or somewhat higher than the estimation made by that of a simple arithmetical progression.

Unfortunately, these assumptions as to a uniform increase or decrease of numbers are largely arbitrary or conjectural, and but rarely agree with the actual facts as found by the next census. Thus the population of Cardiff as estimated in 1901 by the Registrar-General was 200,808, but when actually enumerated by

that year's census was found to be 164,420 only; that is, the rate of increase of population during the ten years 1891–1900 had been much less than in the preceding decennial period. In a similar way the total population of England and Wales at the census of 1901 was found to be 32,526,075, showing a rate of increase during the ten years 1891–1900 of 12·17 per cent. as against 11·65 between 1881–90.

The same thing was found to have occurred in regard to the populations of most of the large towns, with the result that their calculated death-rates had been returned too low. As examples one may give the following towns, whose enumerated populations differ more than 10 per cent. from the estimated: Newcastle-on-Tyne (*minus* 10·5 per cent.), Swansea (*minus* 11·9 per cent.), Blackburn (*minus* 15·5 per cent.), Cardiff (*minus* 18·8 per cent.), and Burnley (*minus* 19·5 per cent.). These erroneous estimates of population have obvious vitiating effects on vital statistics. Thus Burnley, which is an extreme case, had 2214 deaths in 1900, and the death-rate based on the estimated population for that year was 19·6 per mille; when worked out on the enumerated or census population of 1901 it was 22·8 per mille. The only remedy is a more frequent enumeration, as offered by a quinquennial census.

As the Registrar-General has pointed out, the official method of calculating populations by the assumption of an equable rate of growth is only trustworthy in the case of very large communities, where any abnormal increase in one direction is sure to be counterbalanced by an abnormal decrease in another. It is hardly suited for very small communities, where growth is very often most irregular and spasmodic.

A moment's reflection will show that many circumstances may help to quicken or slow the increase of a population. The increase in any given population may be either *natural* or *actual*. The former is merely the excess of births over deaths, while the latter is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The facts revealed by the last census, in 1901, showed a decline in the natural increase of population for England and Wales; this was not due to any increased mortality, but rather to a decline in the birth-rate. For the whole country the actual increase, as shown by the last census, also showed a decline, due mainly to an excess of emigration over immigration during the last decennium. As a general rule, in towns the *actual* increase is greater than the *natural*, simply because there is a natural tendency for people to migrate from rural to urban districts; and with regard to such local migrations, at present we have no available or

systematic record. It is well known that in times when trade is bad in certain localities, a considerable movement of the population occurs to other parts, and *vice versâ*.

Although not officially recognized by the Registrar-General, there are several methods of checking estimated populations, which, if used judiciously, are of great value. Amongst such are examinations of inhabited houses as ascertained from the rate-books, and then, assuming the density to remain the same, to multiply the number of inhabited houses by the average number of persons per house. Care, however, must be taken to allow for any marked change in the class of new houses built, whether containing fewer or more occupants than others, and, too, to allow for block buildings, flats and large hotels, all of which are liable to seriously affect statistical results. Another useful method for checking the calculation of a present population, suggested by Newsholme, may be derived from the birth-rate of a place. It is based on the assumption that the birth-rate remains the same for a series of years as it was found to be at the time of the last census. Thus, in Wandsworth, the average birth-rate for the decennium 1872–81 was 35·68 per 1000, and the number of births in 1881 was 7582; therefore assuming that 35·68 was the number of births from one thousand of population, 7582 was the birth-rate of 212,500 people, or, $\frac{7582 \times 1000}{35 \cdot 68} = 212{,}500$. As a matter of fact, the actual census return for Wandsworth, in April, 1881, was 210,434, an astonishingly close approximation of results.

Age and Sex Distribution.—This is sometimes spoken of as the constitution of a population, inasmuch as it shows the proportion in which males and females, and persons of different ages or of different callings, enter into the composition of the community. These figures and facts are of course only obtained at each census, and generally may be taken to remain constant till the next census. The effect which these facts have upon mortality statistics will be explained later on; at present, allusion need only be made to the very marked difference which exists in the age distribution between the populations of town or urban and those of rural districts. The 1901 census gives for England and Wales the following age and sex distribution of the population per million persons of all ages:—

	Urban districts			Rural districts.		
	Persons	Males.	Females.	Persons	Males.	Females.
All ages .	25,058,355	12,014,089	13,044,266	7,469,488	3,714,524	3,754,964
0 to 5 .	2,865,349	1,428,840	1,436,509	851,359	426,521	424,838
5 ,, 10 .	4,166,375	2,074,092	2,092,283	1,332,010	668,440	663,570
10 ,, 15 .	1,513,856	748,560	765,296	472,676	248,452	224,224
15 ,, 20 .	2,538,483	1,218,584	1,319,899	687,670	362,688	324,982
20 ,, 25 .	4,274,930	1,994,668	2,280,262	1,034,605	502,933	531,672
25 ,, 35 .	3,608,755	1,719,581	1,889,174	967,959	472,544	495,415
35 ,, 45 .	2,644,467	1,273,068	1,371,399	779,343	384,371	394,972
45 ,, 55 .	1,779,152	838,412	940,740	602,428	295,340	307,088
55 ,, 65 .	1,082,108	481,803	600,305	438,238	211,047	227,191
65 ,, 75 .	473,711	195,568	278,143	237,102	112,993	124,109
Over 75 .	111,169	40,913	70,256	66,098	29,195	36,903

This table shows that, as compared with the country districts, in the towns of England and Wales there is a great excess of persons from 15 to 45 years of age, and a small proportion of children between 5 and 10 years of age. The probable explanation of these figures is the persistent immigration of young adults from the country to the urban areas in the one case, and the higher infantile mortality of the towns than of rural districts in the other. The proportion of females to males, of all ages, is much higher in towns than in the country, being 108 to 100 in the former, but only as 101 to 100 in the latter. These proportions are only manifest after the 10 to 15 age period, when the girls begin to migrate into the towns as domestic servants.* The migration of girls into towns is soon followed by that of boys, with the result that the unequal proportion of the two sexes in towns in the 15 to 20 age period is considerably reduced, and continues to be so during all the more active working ages, or the period from the end of the 25th to the end of the 45th year of life. In the later years of life, the disproportion between the sexes in the towns again increases, so much so that in the 55 to 65 years period the women are 20 per cent. more numerous in towns than the men, but only about 5 per cent. more numerous in the country. In the 65 to 75 period the excess is 33 per cent. in the towns, and only 7 per cent. in the country; while in the over 75 years period the excess of women becomes 55 per cent. in the towns, and only 15 per cent. in the rural districts.

As the Registrar-General has pointed out, this increasing excess of females in the late-age periods, so far as it is common to both towns and country, is, of course, due to the fact that

women are longer lived than men—that is, they survive when the men die off. The greater excess of women over men in towns than in the country is less easy of explanation. It may be due to the fact that men, as they get old, leave the towns where the struggle for existence is so much the more keen, and retire into the country more rapidly than do the women; or it may be due to differences between the conditions of town and country life being more hostile to old men than to old women. Possibly both causes are at work. We know that for some reason or other urban life is exceptionally fatal to elderly men, and that towns offer, even to those in advanced age, more chances of comparatively easy work to women than to men; hence there is more inducement for women than for men to remain in the towns when they have grown old, especially as town life is much less healthy for men than for women. The practical importance of this question of age and sex distribution in vital statistics will be apparent when we come to consider the value of death-rates.

Birth and Marriage Rates.—The Births and Deaths Registration Act of 1874 compels every birth to be registered within 42 days of its occurrence. The number of births per 1000 persons living, or birth-rate, as it is so called, averaged 29.4 per 1000 in England and Wales, during the decennium 1893–1902, the highest rate of 36·3 ever recorded in this country having been reached in 1876, and the lowest 28·4 in the year 1903. The birth-rate naturally varies greatly in different towns or localities, being higher in towns and during times of commercial prosperity, and of course lower in rural districts and during periods of trade depression. Bad trade and bad harvests also diminish the number of marriages, and consequently lower the number of children born.

The birth and marriage rates are readily found by a simple proportion sum; thus, if the population of a town be 13,621, and the number of births and marriages during the year are respectively 441 and 215, then $\frac{441}{13621} \times 1000 = 32{\cdot}3$ birth-rate per 1000, and $\frac{215}{13621} \times 1000 = 15{\cdot}7$ marriage-rate per 1000. This method of stating the ratio of births, marriages, or deaths in one year, as per thousand persons living in a place, is the most usual and convenient, but occasionally it may be necessary to compare these rates for shorter periods, say weeks, months, or quarters; in which case it is done in the following way. Suppose it is required to know the birth-rate during $\frac{1}{n}$ part of a year, then—

$$\frac{\text{Number of births during the period in question}}{\text{Population in the middle of the year}} \times n \times 1000 =$$

birth-rate of period in question. Taking the preceding example, and required the birth-rate during one week, or $\frac{1}{52 \cdot 17747}$ part of a year, during which period 10 births have taken place, we get $\frac{10}{13621} \times 52 \cdot 17747 \times 1000 = 38 \cdot 19$ or birth-rate.

When comparing one community with another, to be strictly fair, the birth-rate should be calculated on the total population only after it has been reduced to a common or normal constitution as regards sex, age, and marriage. This is the best secured by calculating the birth-rate on the number of women between 20 and 40 years of age who constitute the great majority of child-bearing mothers. More males appear to be born than females, in the proportion of 104 to 100. The number of illegitimate children born is diminishing; formerly it was as much as 5 per 1000; in 1903 the proportion was as low as 1·2 per 1000 persons living, or 39 per 1000 births. This illegitimate birth-rate varies much in different districts; thus the registration counties in which the proportion of illegitimate to total births was highest, were Lincolnshire, Norfolk, Herefordshire, Shropshire, Cumberland, and Carnarvonshire.

Closely connected with the birth-rate is that of the marriage-rate, and both are intimately involved in the question of population increase. In this country, the number of married persons per 1000 of living has averaged during the last 50 years something like 16 or 17; but of late years it has steadily fallen. In 1903, 16 persons per 1000 living married; the rate in 1886 was only 14·2. Like the births, the marriages usually closely follow the fluctuations in commercial prosperity. The slight rise in the marriage-rate in 1891 coincided, however, contrary to the almost universal rule, with a considerable decline in the value of British trade. The mean age of marriage seems to be, for males, 28; for females, 26; while the average number of children to each marriage is roughly 4½. In France and some foreign countries the production of children is deliberately restricted in relation to the possible maintenance of them at home; with the result that the total populations are diminishing. In this country, we have no need to discourage the expansion of the population, for our colonies are in need of more inhabitants, and our industries of more work-people. In fact, it is the absence of such restrictions on population in Great Britain which has enabled us to establish our colonial empire and extend the British nation all over the world. It is as much a mistake to suppose that the inhabitants of a country are in proportion to their food, as it is to think that the productions of a country are in proportion to the number of its inhabitants. The truth is, the population that

a country sustains does not depend exclusively on the amount of subsistence existing in it at any one time, but rather that the produce of a country is limited chiefly by the character of its inhabitants, and the more civilized and cultured they are, the greater will be the products of their industry. Unfortunately, population is often out of the place where it is wanted or could be most productive; but at no time can it be said that the population of the world is excessive. And as for any need to restrict the production of children as advocated by Malthus, it is as uncalled for as it is mischievous, and amounting as it does to a policy of depopulation, it means the gradual reduction of England, in the presence of the great continental nations, to the level of a second-rate power.

Death-rates.—By the Births and Deaths Registration Act of 1874, all deaths must be registered within five days of their occurrence. In 1903, the deaths registered in England and Wales were in a proportion of 15·4 to every 1000 persons living. This is the lowest rate attained hitherto. The death-rate is obtained in exactly the same way as that for births—by multiplying the actual number of deaths from all causes into 1000, and dividing the product by the population; this is known as the general or gross death-rate. In a similar way as explained above for calculating the weekly or quarterly birth-rate, so is the annual death-rate for the week, month, or quarter obtained.

Thus, take a town with a population of 20,000 and the deaths in any week being 8, the annual death-rate for that week will be 11, or $\frac{4}{20000} \times 52·17747 \times 1000 = 10·87$. These so-called weekly death-rates are convenient for reports, but are not reliable data on which to compare the relative conditions of places, as much of the mortality often depends upon epidemics, weather, and other causes of a temporary nature. These death rates, as published for each week by the Registrar-General, must therefore not be regarded as actual rates, but rather as annual rates per 1000, representing the number who would die supposing the same proportion of deaths to population held good all through the year. Their chief value is for contrasting mortality rates of any given place at corresponding periods of some previous year. The value of the general death-rate has been much criticized on the ground that it is much influenced by movements of the populations, by the presence of large institutions, such as hospitals, by the age and sex distribution of the population, and by the birth-rate. All this is quite true, but still, if due correction be made, it is probably, in the case of large populations, the most trustworthy test we have of relative vitality. The corrections most advantageously applied to general death-rates are: (1) for

non-resident, or migratory people; (2) for age and sex distribution.

The correction for a migratory population is most difficult to apply, as it is not easy to trace and control the facts relating to visitors and immigrants. In the case of watering-places and favourite residential towns, corrections in this direction are most important, and are largely made by the officials from materials obtainable from the sub-registrars; but, even under the best supervision, considerable disturbance and fallacies to the statistics occur. Closely allied to the consideration of migration is the effect which public institutions, such as poor-houses or hospitals, exert on local death-rates, as the disturbance arising from them is due to migration into them from neighbouring districts. To meet this difficulty, the rule is to deduct the deaths of those inmates drawn from outside areas, at the same time adding the deaths of proper inhabitants of the place which may have occurred in other institutions outside the district. Each sanitary authority in London is supplied quarterly by the Registrar-General with particulars of death of their inhabitants in outlying districts, so that the deaths in all these cases may be apportioned to their proper districts. Unfortunately such accuracy does not pertain to rural districts, but it is to be hoped, in course of time, even this will be done. All general death-rates require to be corrected for age and sex distribution. Females live longer than males. It follows, therefore, that if two towns were in an equally healthy state, but that one of them contained a larger proportion of females than the other, the one with the lower proportion of females would have the higher death-rate. Similarly, there is a great tendency to death among infants; this liability to die reaching its minimum from between ten to fifteen years of age, and afterwards steadily increasing throughout life. In this respect, there was a remarkable increase of mortality at the advanced ages in 1890–91, due to the prevalence of epidemic influenza.

The following table shows the mean annual death-rates in England and Wales during 1902–3 per thousand persons living at each age period:—

Age groups.	All persons 1902.	All persons 1903.	Males 1902.	Males 1903.	Females 1902.	Females 1903.
0-5	49·1	47·3	53·7	51·7	44·5	42·9
5-10	4·0	3·5	3·9	3·4	4·1	3·5
10-15	2·2	2·0	2·2	2·0	2·3	2·1
15-20	3·2	2·9	3·3	3·0	3·1	2·8
20-25	4·1	3·7	4·5	4·1	3·8	3·4
25-35	5·7	5·4	6·2	5·8	5·3	4·9
35-45	9·4	8·8	10·5	9·6	8·5	8·1
45-55	15·7	14·9	18·0	16·9	13·6	13·0
55-65	29·6	28·1	33·6	32·1	26·1	24·6
65-75	61·6	59·2	67·8	65·2	56·6	54·5
75-85	129·5	123·1	138·4	132·6	123·0	116·2
Over 85	264·9	253·8	274·7	268·3	259·1	245·2
All ages	16·2	15·4	17·4	16·5	15·2	14·4

It follows, therefore, that a town, a large proportion of whose inhabitants were at the most viable age, would have a lower death-rate than a town equally healthy, in which the ages of the people were less favourable to long life; just as it would be if the one town had a much larger population of females than the other. In order to neutralize these errors, the Registrar-General has devised a method by which they can be corrected.

This method, based primarily upon the death-rate of each sex at different ages throughout England and Wales, provides a series of factors by which the recorded death-rates of the great towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors, the recorded gross death-rate of any of these towns can be lowered or raised to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. This new rate is called the *corrected death-rate*. The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical (arbitrary) *standard death-rate*, calculated on the hypothesis that deaths at each age period were at the same rate as in England and Wales during the decennium 1891-1900, the death-rate at all ages in England and Wales during that period having been 18·06 per 1000. Owing to the proportions of persons of low mortality being excessive in most towns, their recorded death-rates are too low, and in consequence the factor for their correction is in most cases above unity, the only exceptions being Hastings, Southampton, Ipswich, Yarmouth, Norwich, and Plymouth. The table below gives these

factors for the chief towns as issued by the Registrar-General in 1905, along with their recorded and corrected death-rates per 1000 living in 1904.

Towns, in the order of their corrected death-rates.	Standard death-rate.	Factor for correction for sex and age distribution.	Recorded death-rate, 1904.	Corrected death-rate, 1904.	Comparative mortality figure, 1904.
Cols.	1.	2.	3.	4.	5.
England and Wales .	18·194	1·0000	16·23	16·23	1000
England and Wales, less the 76 towns . . .	18·83	0·9662	15·40	14·88	917
76 towns . . .	17·13	1·0621	17·24	18·31	1128
Hornsey	15·96	1·1400	8·44	9·62	593
Kings Norton . . .	17·40	1·0456	10·56	11·04	680
Willesden	16·96	1·0728	11·19	12·00	739
Hastings	18·92	0·9616	13·16	12·65	779
Walthamstow . . .	17·21	1·0572	12·17	12·87	793
Handsworth (Staffs.) .	16·53	1·1007	11·80	12·99	800
Leyton	17·69	1·0285	12·67	13·03	803
Southampton . . .	18·30	0·9942	13·74	13·66	842
East Ham	17·06	1·0665	13·08	13·95	860
Smethwick	16·63	1·0940	12·84	14·05	866
Devonport	17·35	1·0486	13·42	14·07	867
Croydon	17·75	1·0250	13·80	14·15	872
Reading	17·59	1·0343	13·85	14·33	883
Bournemouth . . .	17·22	1·0566	13·60	14·37	885
Northampton . . .	17·50	1·0397	13·84	14·39	887
Tottenham	16·86	1·0791	13·86	14·96	922
Ipswich	18·63	0·9766	15·50	15·14	933
Coventry	18·15	1·0024	15·33	15·37	947
Leicester	17·05	1·0671	14·51	15·48	954
Barrow-in-Furness . .	16·01	1·1364	13·75	15·63	963
Wolverhampton . . .	17·59	1·0343	15·48	16·01	986
Bristol	17·73	1·0262	15·62	16·03	988
Great Yarmouth . .	19·88	0·9152	17·53	16·04	988
Cardiff	16·73	1·0875	14·83	16·13	994
Burton-on-Trent . .	16·93	1·0747	15·02	16·14	994
Rotherham	17·59	1·0343	15·80	16·34	1007
Brighton	18·46	0·9856	16·60	16·36	1008
West Bromwich . . .	18·04	1·0085	16·27	16·41	1011
Derby	16·88	1·0778	15·30	16·49	1016
Aston Manor . . .	16·41	1·1087	15·01	16·64	1025
Wallasey	16·63	1·0940	15·22	16·65	1026
York	17·67	1·0297	16·23	16·71	1030
Halifax	16·79	1·0836	15·45	16·74	1031
Newport, Mon. . . .	16·84	1·0804	15·67	16·93	1043
West Hartlepool . .	16·57	1·0980	15·46	16·98	1046
Portsmouth	17·75	1·0250	16·88	17·30	1066
Grimsby	16·99	1·0709	16·22	17·37	1070

Towns, in the order of their corrected death-rates.	Standard death-rate.	Factor for correction for sex and age distribution.	Recorded death-rate, 1904.	Corrected death-rate, 1904.	Comparative mortality figure, 1904.
Cols.	1	2	3	4	5
Norwich	19·05	0·9551	18·23	17·41	1073
London	17·31	1·0511	16·63	17·48	1077
West Ham	17·01	1·0696	16·45	17·59	1084
Plymouth	18·66	0·9750	18·54	18·08	1114
Sheffield	16·88	1·0778	16·79	18·10	1115
Stockton-on-Tees	17·35	1·0486	17·56	18·41	1134
Nottingham	17·27	1·0535	17·70	18·65	1149
Huddersfield	16·96	1·0728	17·51	18·78	1157
Walsall	17·18	1·0590	17·88	18·93	1166
Bury	16·25	1·1196	16·92	18·94	1167
South Shields	17·19	1·0584	17·90	18·95	1168
Hull	17·75	1·0250	18·56	19·02	1172
Bolton	16·09	1·1308	16·91	19·12	1178
Blackburn	16·09	1·1308	16·93	19·14	1179
Swansea	16·96	1·0728	18·02	19·33	1191
Bradford	16·46	1·1053	17·64	19·50	1201
Gateshead	17·26	1·0541	18·51	19·51	1202
Rochdale	16·45	1·1060	17·71	19·59	1207
Leeds	16·68	1·0908	18·02	19·66	1211
Tynemouth	17·62	1·0326	19·22	19·85	1223
Sunderland	17·64	1·0314	19·46	20·07	1237
Oldham	16·18	1·1245	18·19	20·45	1260
Newcastle-on-Tyne	16·87	1·0785	19·36	20·88	1287
Merthyr Tydfil	17·16	1·0603	19·73	20·92	1289
Birkenhead	17·07	1·0658	19·64	20·93	1290
Preston	16·63	1·0940	19·20	21·00	1294
Rhondda	16·54	1·1000	19·11	21·02	1295
Stockport	16·84	1·0804	19·65	21·23	1308
Birmingham	16·91	1·0759	19·88	21·39	1318
Warrington	16·89	1·0772	19·90	21·44	1321
Middlesbrough	16·71	1·0888	19·78	21·54	1327
Bootle	16·50	1·1027	19·61	21·62	1332
Burnley	16·14	1·1273	19·51	21·99	1355
St. Helens	16·79	1·0836	20·89	22·64	1395
Hanley	16·67	1·0914	20·89	22·80	1405
Salford	16·47	1·1047	21·18	23·40	1442
Wigan	16·51	1·1020	21·48	23·67	1458
Manchester	16·29	1·1169	21·27	23·76	1464
Liverpool	17·00	1·0702	22·59	24·18	1490

If the corrected death-rate in each town be compared with the death-rate at all ages in England and Wales taken as 1000, it gives a number known as the *comparative mortality figure*, as shown in the last column of the preceding table. These figures may be expressed in another way, by saying that after correction has been made for differences of age and sex distribution, the

same number of people that gave 1000 deaths in England and Wales in 1904, gave 1211 in Leeds, 954 in Leicester, and 1294 in Preston. Or we can say that in 1904 the recorded death-rate for the whole of England and Wales was 16·23; and the recorded death-rate for Blackburn is 16·93, with its factor for correction as 1·1308. Then $16·93 \times 1·1308 = 19·14$ as the corrected death-rate for Blackburn, and $\frac{19·14}{16·23} \times 1000 = 1179$ as its figure of comparative mortality.

The following table gives the variations in the death-rates during recent years in the groups of districts which are taken to represent severally the urban and rural portions of England and Wales:-

Mortality from all causes, at all ages, per 1000 persons.		Corrected rates per 1000	
		Average, 1898–1902	Year, 1904.
Both sexes	England and Wales	17·388	15·419
	Urban counties	19·204	16·996
	Rural counties	14·294	12·884
Males	England and Wales	18·562	16·506
	Urban counties	20·562	18·236
	Rural counties	15·080	13·607
Females	England and Wales	16·288	14·401
	Urban counties	17·932	15·834
	Rural counties	13·559	12·208

Infantile Mortality.—The calculations of infant and child mortalities demand special remark; particularly as it is by no means uncommon to find them worked out on the population, or on the number of deaths at all ages. The proper, the most simple, and most accurate way is rather to utilize the birth returns, and calculate out the ratio of deaths of infants under one year to the number of actual births in the latter half of the preceding year and the former half of the current year. The greatest care should be given to child mortality, or the death-rate of those under five years of age, as it constitutes an important and instructive index of health conditions. In 1903, the proportion of deaths of infants under one year of age to 1000 registered births was 132. The rate differs widely in different counties and towns; the general rule being that the rate is lowest in the purely agricultural, and highest in the mining districts, and in those with textile industries.

The chief causes of infantile mortality, common to every locality, are briefly: premature birth, congenital defects, hereditary

tendencies, inexperience and neglect of mothers, industrial conditions, improper food, and overlaying.

The following table shows the infant mortality per thousand births in England and Wales, and in some of the 76 large towns for the year 1904. From this it will be seen that the highest proportions of deaths under one year to births registered were in the towns of Preston, Blackburn, and Salford.

District or town.	Deaths of children under one year of age to 1000 births in 1904.	District or town.	Deaths of children under one year of age to 1000 births in 1904.
England and Wales	132	Birkenhead . . .	181
76 large towns . .	160	Liverpool . . .	196
		Bolton	168
London	146	Manchester . . .	187
West Ham . . .	162	Salford	192
Croydon	130	Oldham	156
Brighton	134	Burnley	229
Portsmouth . . .	142	Blackburn . . .	191
Plymouth . . .	172	Preston	185
Bristol	134	Huddersfield . .	136
Cardiff	146	Halifax	128
Swansea	174	Bradford . . .	166
Wolverhampton . .	155	Leeds	175
Birmingham . . .	197	Sheffield . . .	158
Norwich	180	Hull	178
Leicester	167	Sunderland . . .	164
Nottingham . . .	176	Gateshead . . .	174
Derby.	143	Newcastle . . .	156

A very frequent source of error in vital statistics is made in calculating the mean death or other rate of two populations or communities; these are often spoken of as *combined death-rates*. The error usually arises from failing to take into account the proportion which the two populations or groups bear to one another. Thus suppose two towns each contain 30,000 inhabitants, and have respectively mortalities of 22 and 16, their mean or combined death-rate would be $\frac{22+16}{2}$ or 19. But suppose one of the towns have 42,000 inhabitants and the other 18,000, and have respectively the above mortalities, their combined death-rate will then not be the mean of their two separate death-rates, but as follows:—

One town of 42,000 people with a death-rate of 22 per 1000 = 924 deaths.
" " " 18,000 " " " 16 " = 288 "

or 60,000 people give 1212 deaths,

and $\frac{1212 \times 1000}{60{,}000} = 20{\cdot}2$, the true combined death-rate per 1000.

Death-rates are said to be largely influenced by the birth-rate, and by densities of population. With regard to the influence of the birth-rate upon the death-rate much controversy has prevailed. To a great extent this has been unnecessary, and has arisen from a misconception as to the true meaning of the relation between the birth- and death-rates. If we imagine a population in which there has been a high birth-rate for one or more years, it is clear such must contain a larger proportion than usual of young children, and inasmuch as the death-rate of young children is higher than that of all others except the aged, the general death-rate of that population will be raised; but this condition is to a large extent counterbalanced by the fact that a high birth-rate implies the presence in that particular population of a large proportion of persons of the child-bearing age, that is, of an age-period when the mortality is unusually low. So, again, if the high birth-rate be continued for any length of years, it means not only a large proportion of children and of persons at reproductive ages, but also of young adults, among whom a low rate of mortality also prevails. The real influence of the birth-rate upon the death-rate, therefore, is not one which can be well expressed as a low birth-rate causing a low death-rate, or a high birth-rate producing a high death-rate, but rather that the average age of a population governs the death-rate, and that the lower the mean age of the living, the lower should be the death-rate, and, by inference, that the death-rate really controls the birth-rate, because the lower it is the more chance is there of there being a large proportion of persons at the child-producing ages. If a high death-rate follows a high birth-rate, it reasonably suggests an excessive infantile mortality; very often low death-rates and low birth-rates co-exist, but it does not follow that the one is necessarily caused by the other.

The influence exerted by density of population on mortality and death-rates has long been recognized. The density may be either expressed as so many persons to a square mile or as acres to a person. Farr found that the mortality increases with the density of a population; not in direct proportion to the density, but as their sixth root; while, according to Ogle, this influence of the density does not affect the mortality unless there be more than four hundred persons to the square mile. The practice of building back-to-back houses, so prevalent in Yorkshire and Lancashire, and without provision for through ventilation, illustrates very clearly the evil effects of crowding populations, and has been well sifted by the reports of Barry and Gordon Smith to the Local Government Board in 1888.

Increased density of population gives rise to filth conditions, to

the more rapid spread of infectious diseases, phthisis, accident, and other evil conditions, the outcome of co-existent poverty and occupation. It is probably by and through these, rather than from mere overcrowding, that density of population in any way influences the death-rate of a community.

Causes of Death.—It is not sufficient to know the death-rate of a community; it is necessary to know and inquire what rates the different causes of death give when the deaths are distributed to their several classes. Although the death returns obtained from registrars are principally derived from certificates signed by either doctors or coroners, and, as such, should be clear statements of the precise cause of death, still even now the cause of death in many cases is both vague and ill-defined. Each year, however, shows improvement in this direction, with the result that the registration of death-causes is becoming gradually more and more accurate and complete.

The death-rate from zymotic or special febrile diseases is an important fact to be noted among all communities, as it furnishes a very popular standard as to their general healthiness. But it will readily be understood that it is liable to great fluctuations according to the greater or less prevalence of one or other of those diseases, with the result that a so-called mean zymotic death-rate is often of little value. Thus, say in a given community the zymotic death-rate be excessive owing to the epidemic prevalence of the two zymotic diseases, measles and whooping-cough. Owing to these diseases not being either usually or truly dependent upon defective sanitary conditions, their excessive prevalence, as evidenced by an increased zymotic death-rate, furnishes less clue as to the health-condition of the community than would an equally high zymotic mortality rate, owing to such diseases as diphtheria or enteric fever, which are more directly the expression of faulty sanitary states.

Zymotic disease.	England and Wales.		76 large towns.
	Ten years, 1890 99.	1903.	1904.
Small-pox	13	23	10
Measles	440	274	470
Scarlet fever	183	125	120
Diphtheria	242	182	190
Whooping-cough	402	285	400
Diarrhœa	672	551	1200
Enteric fever	173	100	110

Of late years the zymotic death-rate has shown a steady tendency to fall; but so far, the best endeavours of sanitarians have not been able to get the death-rates of the chief diseases of this class much below the preceding rates *per million* living in England and Wales and in the 76 large towns.

Other influences which largely disturb death-rates are sex, age, and occupation. The mortality among women appears to be higher than among males for such diseases as rheumatism, anæmia, chlorosis, erysipelas; while for affections connected with childbirth, it is, of course, limited to the female sex. On the other hand, men die more than women when affected with such diseases as syphilis, diabetes, rickets, typhus, meningitis, and hydrophobia.

The influence of age upon mortality rates is very marked in certain diseases. Thus, phthisis or consumption is at its lowest prevalence between the ages of 5 and 12, but increases up to 47 years of age, after which it lessens. Small-pox mortality is highest in the first and twenty-fifth years, while diarrhœa, whooping-cough, measles, and diphtheria all have their highest death-rates during the first few years of life. Cancer is a disease which appears rarely to affect the young, but tends to increase after 28 years of age. Diseases connected with the heart and circulatory system increase in their mortality rates from birth upwards. The total death-rate, and the death-rates from affections of the nervous system, lungs, and bladder, all appear to be at their lowest between the tenth and fifteenth years of life.

Occupation.—The more recent investigations of Tatham, as well as those of Ogle and Arlidge, have thrown considerable light upon the influence which occupation has upon mortality. Some callings are much less favourable to health than others; some again, while being relatively healthy, are dangerous. The chief circumstances which render certain employments more or less hurtful to health are, bad ventilation and overcrowding of workrooms; exposure to weather, or extremes of heat and cold; inhalations of vapours, gases, or metallic, mineral, or organic dust; overstrain, and mental anxiety; and intemperance. Many difficulties and fallacies underlie all comparative statistics of class mortalities, unless due allowance be made for the age at which such employments are followed, as well as the question of the class of person actually engaged, and the importance of differentiating between employer and employed.

The following table shows the comparative mortality amongst persons of various occupations, as gathered from the more recent statistics:—

Occupation.	Comparative mortality figure. Calculated on four age groups	Calculated on two age-groups (modified mortality figure).		
	1890–92	1890–92	1880–82.	1860,'61 '71
All males	1000	1000	942	960
Males in selected healthy districts	679	693	-	-
Occupied males	953	947	910	
Unoccupied males	2215	2338	2065	–
Clergyman, priest, minister	533	547	524	605
Barrister, solicitor	821	820	793	882
Law clerk	1070	1028	1084	1536
Physician, surgeon, etc.	966	957	1058	1073
Schoolmaster, teacher	604	571	677	893
Artist, sculptor, architect	778	777	868	955
Commercial traveller	961	926	893	1106
Commercial clerk	915	872	938	1183
Carman, carrier	1284	1247	1201	-
Bargeman, waterman	1199	1194	1230	1253
Farmer, grazier	563	591	595	673
Labourer, agricultural	666	681	660	—
Gardener, seedsman	553	568	564	642
Fisherman	845	843	752	786
Brewer	1427	1407	1282	1552
Innkeeper, servant	1659	1665	1525	1490
Publisher, stationer	833	825	777	887
Chemist	926	916	957	1057
Tobacconist	1002	1001	944	989
Grocer	644	664	726	744
Draper, warehouseman	1014	984	833	1132
Bookbinder	1060	1043	1099	1179
Printer	1096	1048	1009	1144
Watchmaker	977	967	878	—
Butcher	1096	1066	1103	1130
Baker	920	905	902	989
Tailor	989	999	990	1043
Shoemaker	920	929	867	889
Hairdresser	1099	1070	1250	1242
Tanner, fellmonger	756	752	857	980
Scissors, file, and needle-maker	1412	1398	1198	1169
Locksmith, gasfitter	925	914	910	1038
Blacksmith, whitesmith	914	909	916	930
Bricklayer, mason, builder	1001	1002	913	1033
Plasterer, paper-hanger	1087	1070	844	972
Plumber, painter, glazier	1120	1091	1132	1234
Sawyer	768	789	802	798
Wool manufacturer	996	980	971	—
Cotton manufacturer	1176	1122	1024	—
Wool, silk dyer, etc.	1370	1351	953	999
Paper manufacturer	904	876	675	841

Occupation.	Comparative mortality figure. Calculated on four age-groups.	Calculated on two age-groups (modified mortality figure).		
	1890–92.	1890–92.	1880–82.	1860,'61,'71
Potter, earthenware . .	1706	1639	1638	1390
Glass manufacturer . .	1487	1431	1121	1150
Coal miner, Derbyshire .	727	693	691	- -
Tin miner	1409	1405	1730	1363
Coal miner, South Wales	1145	1102	1017	1218
Costermonger, hawker .	1652	1679	1771	1606
General labourer . . .	1413	1399	1904	1596
Chimney sweep . . .		1321	1430	1610

The comparative mortality figures as given in the above table simply mean that, for any given occupation, there would be that number of deaths for every 1000 deaths in the general male population of similar numbers and identical age distribution.

In attempting to judge the health of a community by statistical evidence, the greatest importance is attached to the following points, namely: The total corrected death-rate, the zymotic death-rate, and the infant mortality. All these have been discussed, and the various sources of error connected with them explained. But, besides these, certain other evidence is usually considered, mainly as a test of the mean or average longevity of the population. This evidence consists of facts relating to what is known as "the mean age at death," "the probable duration of life," and "the expectation of life."

The **mean age at death** is of course obtained by adding up the ages of persons dying, and dividing this sum by the total number of deaths. In this country, the mean age of death averages 42 for males, and 45 for females. This fact is, however, an imperfect and crude test or index of longevity, simply because it is so largely affected by the birth-rate. If the birth-rate be high, there will be in consequence a greater proportion of infants or young children in the population. These we know have a relatively high death-rate, with the result that the average age of death will be proportionately reduced.

The **probable duration of life** is practically the age at which exactly half of any given number of children born alive will have died; or, in other words, there are equal chances of their dying before and after that age. It is sometimes spoken of as the

equation of life, or *vie probable* of French writers. All these terms are more or less unfortunate, as there is a probability for every possible duration of life. Regarded strictly as defined above, the probable duration of life is of no great value as a test of longevity; it can only be obtained from what is called a life-table, and as so determined for England and Wales, gives the probable duration of life for each male 47 years, and for each female 52 years. The probable duration of life is often confounded with another statistical expression, called the *mean duration of life*, which is the probable or likely duration of life from birth, and, by French writers, called the *vie moyenne*. If we imagine an absolutely stationary population, that is, one in which age and sex distribution does not change, then, starting from birth, the mean duration of life would be identical with the mean age at death, and with the expectation of life as determined by means of life-tables. But such a stationary population is rare, and in an ordinary community, whose numbers are constantly being disturbed by migration or other causes, the mean duration of life really signifies the present age in years *plus* the probable duration of life after having attained a given age, and which is more commonly called the mean after lifetime, or expectation of life. For comparative purposes, it is often more convenient to employ the term mean duration of life as indicating the expectation of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, expectation of life, must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has. Its estimation is made by means of what is called a Life Table, and which is nothing more than a table constructed from census figures on the basis of the number living and the number dying at each age. Such a table shows how many out of say a million persons supposed to be born at the same time will survive at the end of each year or term of years. The same table will also show the sum of the number of years which they live, and if this sum of these years be divided by the number living at any given age, the result will be the expectation of life for that given age.

Farr called a life-table a *biometer*, because it really represents "a generation of individuals passing through time," and measures the probabilities of life and death of this generation at birth, and

of the survivors at each successive age-period, until the whole generation is extinct. In order to construct a life-table, it is necessary to have (1) particulars from a census return of the number, age, and sex-distribution of a population; (2) return of deaths for one or more years among this same population, grouped in the same ages or age-periods as have been adopted for stating the census population. A separate table is required to be constructed for each sex, and for this reason the death returns must be distinct for the two sexes.

A life-table can be constructed for either annual or quinquennial intervals; in most tables, an annual interval is adopted for the first five years, and after that five-year periods are taken. The first step is to calculate from the census returns the death-rate per 1000 living for each age or group of ages, and call this D. These deaths may be assumed to be evenly distributed over the whole age-period, so that half the deaths will occur in the first portion of the period, and the other half in the second portion; and the ratio of the final to the initial population is $\frac{1000 - \frac{1}{2}D}{1000 + \frac{1}{2}D}$, which, when simplified, becomes $\frac{2000 - D}{2000 + D}$.

For the construction of a hypothetical life-table, let us suppose that the mortality among infants in a given population is 100 for every 1000. It will be at once evident that if there be 1,000,000 babies born and living at the commencement of a given year, these will be reduced to 900,000 in the course of the year, and this number will commence the second year. Presuming that the data show that the death-rate among children in the second year of life is as high as 50 per thousand living, then applying the foregoing formula, we get $\frac{2000 - 50}{2000 + 50}$ or $\frac{1950}{2050}$ or 0·951019, and the 900,000 children at the beginning of the second year are reduced to 900,000 × 0·951219, or 856,097 at the beginning of the third year. In the same way, knowing the death-rates for the third, fourth, and fifth years of life, the actual numbers of children surviving at the end of those age-periods is calculated. Suppose now, by the end of the fifth year only 650,000 survive out of the original million, and we propose to continue constructing the life-table for quinquennial or five-year periods in place of annual intervals. The calculation is practically the same, substituting for the death-rate of each year the death-rate for each quinquennium. Presume the death-rate among persons aged 5 to 10 years to be 7, then applying the formula for the reduction of the population during this five-year period, we get $\left(\frac{2000 - 7}{2009 + 7}\right)^5$ or 0·965648, and at the end of this quinquennium, or by the end of

the tenth year, the 650,000 will be reduced to 650,000 × 0·965648 = 627,671. This calculation can be repeated for each five-year period until there are no more survivors left.

The first life-table for the whole of England and Wales was constructed by Farr, on the death-rates of 1838–54. A later one is issued from the Registrar-General's office by Tatham, on the basis of the death-rates of 1881–90. The following table gives a portion of the results of this later calculation:—

Age.	Males.				Females.			
	Survivors at each age out of 1,000,000 born	Expectation of life.			Survivors at each age out of 1,000,000 born.	Expectation of life.		
		1881–90.	1871–80	1838–54.		1881–90.	1871–80.	1838–54
0	1,000,000	43·7	44·4	39·9	1,000,000	47·2	44·6	41·9
1	838,964	51·0	48·1	46·7	868,874	53·2	50·1	47·3
2	790,891	53·0	50·1	48·8	823,072	55·2	52·2	49·4
3	772,046	53·3	50·9	49·6	804,142	55·5	53·0	50·2
4	760,167	53·2	51·0	49·8	791,973	55·3	53·2	50·4
5	751,494	52·8	50·9	49·7	783,244	54·9	53·1	50·3
10	733,477	49·0	47·6	47·1	766,151	51·1	49·8	50·3
15	726,194	44·5	43·4	43·2	759,062	46·6	45·6	47·7
20	712,555	40·3	39·4	39·5	744,321	42·4	41·7	43·9
25	693,809	36·3	35·7	36·1	724,788	38·5	38·0	40·3
30	669,279	32·5	32·1	32·8	700,049	34·8	34·4	33·8
35	639,645	28·9	28·6	29·4	670,992	31·2	30·9	30·6
40	604,923	25·4	25·3	26·1	638,912	27·6	27·5	27·3
45	664,437	22·1	22·1	22·8	604,007	24·1	24·1	24·1
50	517,639	18·8	18·9	19·5	564,299	20·6	20·7	20·8
55	462,981	15·7	16·0	16·5	516,375	17·2	17·3	17·4
60	398,400	12·9	13·1	13·5	457,682	14·1	14·2	14·3
65	322,482	10·3	10·6	10·8	385,503	11·3	11·4	11·5
70	238,632	8·0	8·3	8·5	299,220	8·8	9·0	9·0
75	153,890	6·1	6·3	6·5	204,208	6·7	6·9	6·9
80	80,023	4·5	4·8	4·9	114,536	5·0	5·2	5·3
85	29,866	3·3	3·6	3·7	48,133	3·7	3·9	4·0
90	6,786	2·4	2·7	2·8	13,418	2·8	2·9	3·0
95	752	1·7	2·0	2·2	2,124	2·1	2·2	2·3
100	30	1·2	1·6	1·7	157	1·5	1·6	1·8

It has already been stated that from a life-table the expectation of life can be readily calculated. That this is so will be perhaps more clearly understood by the following example. Taking the 1881–90 table, suppose it is required to find the expectation of life for males at the age 35. The rule is, to find the expectation of life at any age, x, add together the years of life lived through by the whole of the life-table population after that

age, and divide by the number of survivors at that age. If we refer to the table, and add together the numbers surviving at each age later than 35, we obtain the figure 3,480,851, which is the number of complete five-year periods lived through by the whole of the life-table population after 35 years of age. But in addition to the five-year periods which a man lives through or completes, each of the 598,860 men surviving at 35 lives through some portion of that particular five-year period in which he dies, and this may be fairly taken to be half. Hence to the 3,133,701 quinquennia already obtained, we must add 598,860 half quinquennia, which gives us a total of 3,433,140 quinquennia, or 17,165,700 years of future life, and this divided among the 598,860 surviving males at age 35, gives them each an expectation of life of 28·6 years.

If we compare the old and new life-tables, it is at once noticeable that there is a greater expectation of life under the new table up to 19 years of age for males, and 45 for females. After these ages, the improvement appears to be less, possibly due to a greater death-rate under the new conditions amongst the elderly people; but this is so much counterbalanced by the saving in life during the earlier years that the total number of survivors up to about 70 for males, and 90 for females, is greater under the new table than in the old. The mean after lifetime at birth for both sexes is about $43\frac{1}{3}$ years in this country; while the probable duration of life lies between 45 and 50 for males, and between 50 and 55 for females.

Farr showed that the mean duration of life, or mean after lifetime, in the absence of proper life-tables, could be approximately calculated from the birth- and death-rates by the following formula, in which B = birth-rate and D = death-rate, while x = expectation of life at birth :—

$$x = \frac{2}{3} \times \frac{1000}{D} + \frac{1}{3} \times \frac{1000}{B}$$

Say a town has a birth-rate of 32 and a death-rate of 28 per thousand, then applying this formula, we get—

$$\frac{2000}{3D} + \frac{1000}{3B} \text{ or } \frac{2000}{84} + \frac{1000}{96} = 34$$

as the mean expectation of life at birth under those conditions.

Willich gives another formula, in which x = the expectation of life at any age, a, between 25 and 75 years, then—

and applying this, say for calculating the expectation of life at 53 years of age, we get $\frac{2}{3}(80 - 53) = x$ or 18 years.

We have now discussed the chief kinds of statistical material generally at the disposal of the sanitarian, but before closing the subject, it is necessary to indicate the chief sources of fallacy in statistics, and the general limits within which they may be used. In an ideal mass of statistics, the facts must (1) be all correctly observed; (2) they must be of the same kind and order; (3) they must be all localized both in regard to time and place; (4) they must be sufficiently numerous to give correct averages, and extend over sufficient length of time. It will be at once obvious that these various essentials are not easy to obtain. It has already been explained that while it is easy enough to ascertain correctly the numbers of a people during a census year, it is less simple to do so during intermediate years. Similarly, differences of degree or intensity, causation or virulence of diseases, render their comparison, by reducing their statistics to the same order and kind, extremely difficult. So, too, the importance of localizing statistics, both in respect of time and place, is made clear by pointing out the absurdity of attempting to construct a particular disease-rate for some health resort from the deaths of persons occurring there from that special affection. The fourth essential for an ideal statistical series is well expressed in the mathematical statement that the error diminishes as the square root of the number of observations; in other words, the smaller the total number of facts, the larger will be the relative percentage of errors displayed by them, and the larger the number of facts collected the smaller will be the margin of error.

The **mean** or **average** has been described as being a number which lies between the highest and lowest of a series of numbers, and has a definite dependence upon the whole of the series. The terms mean and average are often used synonymously; regarded mathematically, there are several kinds of means. Thus, the simple average, or *arithmetic* mean of four numbers, such as a, b, c, d, is conveniently written as $\frac{a+b+c+d}{4}$, but their *geometric* mean would be $\sqrt[4]{abcd}$, while their *harmonic* mean stands thus: $\frac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$, and their *quadratic* mean is—

$$\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}$$

Of course, if the terms of the series of numbers are unequal, then the quadratic mean will be the highest, next the arithmetic,

and then the geometric and harmonic means; but if all the terms of the series are equal, then their means are equal too. The chief practical question in vital statistics is not so much either the value of a true or pure average, or arithmetical mean, or even the probable value of a fixed quantity, but rather the probable value of an *average* or variable quantity; the question being in most cases how far the mean is a trustworthy approximation to the true value sought. One way of securing a correct mean, we have already seen, is by multiplying our facts; while a mode of testing the results of a statistical inquiry, is the determination of the *error*, or the divergence of the individual terms of the series from its mean. This is usually done by what the mathematician calls the law of error, and the following rules given by Jevons are applicable for finding the probable error of a mean result:—

1. Draw the mean of all the observed results.
2. Find the excess or defect, that is, the error of each result from the mean.
3. Square each of these reputed errors.
4. Add together all these squares of the errors.
5. Take the square root of the sum.
6. Divide the square root by the number of results.
7. Multiply the quotient by 0·67449, or $\frac{2}{3}$.

Thus, suppose of the series 21, 32, 27, 25, 98, 33, whose mean is 26, we want to know the probable error of that mean. Now, the apparent errors of each number of the series from the mean are 5, 6, 1, 1, 8, 7; their squares are 25, 36, 1, 1, 64, 49; and the sum of the squares is 176. The nearest square root in whole numbers of this sum is 13, and this divided by 6, or the number of the series, gives 2·16, which multiplied by the factor 0·67449 yields 1·45 as the probable error of the mean of the series.

This calculation of the probable error may be described in another way by saying that it is the error of mean square multiplied by the mathematical constant 0·6745.

The error of mean square is the quadratic mean of the apparent errors, or the result of dividing the square root of the sum of the squares of the apparent errors by the number of terms.

Another test of the value of a series of terms or observations is the determination of their *mean error*, that is, the divergence of the individual terms of the series from its mean. This is conveniently performed in the following way: (1) Find the mean of the series, then find the mean of all the observations *above* the

mean, and subtract the mean from it; this gives the mean error in excess; (2) find the mean of all the observations *below* the mean and subtract it from the mean; this gives the mean error in deficiency. Add the two quantities, and take the half: this is the mean error. In the preceding series of numbers, the mean error of the individual terms is 4·6. It will be at once obvious that the greater the mean error the greater is the need for the series to be extended, in order to compensate for the unreliability of each term of the series, and that the value of any series of observations increases with their number and with their equality.

What is known as Poisson's formula is very frequently employed to determine the liability to error in vital statistics. Thus, say 100 persons are sick with a certain disease, and 33 of them dying, it is required to know whether these numbers are sufficiently great to say that this mortality rate is approximately constant and reliable for the particular disease in question; or whether the figures are too small to accept this death-rate as correct.

Poisson's formula says if μ = the total number of observations, made up of m in the direction of recovery, and n in the direction of death, then $m + n = \mu$; and that the true proportion of each group to the whole number of cases will be in the proportions represented by the formula $\frac{m}{\mu} \pm 2\sqrt{\frac{2 \times m \times n}{\mu^3}}$. In the case cited, the probability of recovering is represented by $\frac{m}{\mu}$ or $\frac{67}{100}$, and of dying by $\frac{n}{\mu}$ or $\frac{33}{100}$.

The possible error is expressed by the second part of the formula $2\sqrt{\frac{2 \times m \times n}{\mu^3}}$, and the smaller will be the value of this possible error the larger the total number of cases, or μ.

Applying this portion of the formula, we get $2\sqrt{\frac{2 \times m \times n}{\mu^3}}$ $= 2\sqrt{\frac{2 \times 67 \times 33}{100^3}} = 0·1330$ to unity, or 13·3 per cent., as the probable error—a figure which is very high, and suggestive of the view that the number of cases is too few for us to accept the mortality rate of 33 per cent. as found, as being approximately correct.

The application of averages or means, when obtained, it will be seen, is of great importance, but only when founded on a

sufficient number of cases. There is always a danger of attaching too much value to means or averages, forgetting how great a range there may be above and below them, and it is by reminding us constantly of this that calculations of the mean and probable errors, as well as the use of Poisson's rule, are so useful.

CHAPTER XI.

SANITARY LAW.

It is not proposed in the following pages to completely review and summarize the whole of the law bearing upon the Public Health, but only to consider so much of it as appears requisite to be known by the head of a household. While the main basis of so-called sanitary law, as now in force in the different parts of the United Kingdom, are the various Public Health Acts, notably those of 1867 (Scotland), of 1875 (England and Wales), of 1878 (Ireland), and of 1891 and 1899 (London), there are in addition a large number of other Acts of Parliament which, in various ways, strengthen or otherwise modify the foregoing. This condition of affairs naturally renders the whole subject of sanitary law a matter of some complexity.

For the purposes of this chapter, in place of analyzing each Act separately, we have deemed it more convenient to consider the general effect of legislation as a whole upon certain matters of sanitary importance, and to limit that summary to the law as applicable to England, Wales, and London.

In order to economize space, certain abbreviations will be employed; these and the full titles of the chief Acts of Parliament bearing upon the Public Health, and referred to in the following abstract, are given below:—

B.A. Board of Agriculture.
C.B.A. Canal Boats Acts, 1877 84.
C.D. (Animals) A. Contagious Diseases (Animals) Acts, 1878 and 1886.
D.C.M.O. Dairy, Cowshed, and Milk-shop Orders, 1885-86 and 1899.
F.W.B. Factories and Workshops Acts, 1878, 1895, and 1901.
H.W.C.A. Housing of the Working Classes Acts, 1885, 1890, and 1903.
I.D.N.A. Infectious Disease Notification Act, 1889.
I.D.P.A. Infectious Disease Prevention Act, 1890.
I.H.A. Isolation Hospital Act, 1893 and 1901.
L.B.A. London Building Act, 1894.
L.C.C. (G.P.) A. London County Council (General Powers) Act, 1890.
L.G.A. Local Government Acts, 1888, 1894, and 1899.

L.G.B. Local Government Board.
M.A. Margarine Act, 1887.
M.M.A. Metropolitan Management Act, 1855.
M.O.H. Medical Officer of Health.
M.S.A. Merchant Shipping Act, 1894.
M.W.A. Metropolitan Water Acts, 1852 and 1871.
O.S.A. Open Spaces Act, 1887.
P.H.A., 1875. Public Health Act (England).
P.H. (Amend.) A. Public Health Act Amendment Act, 1890.
P.H. (Lond.) A. Public Health (London) Act, 1891.
P.H. (Fruit-pickers) A. Public Health (Fruit-pickers) Act, 1882.
P.H. (Interments) A. Public Health (Interments) Act, 1879.
P.H. (Water) A. Public Health (Water) Act, 1878.
P.H. (S.) A. Public Health (Scotland) Act, 1867.
P.H. (I.) A. Public Health (Ireland) Act, 1878.
R.P.P.A. Rivers Pollution Prevention Acts, 1876 and 1893.
S.A. Sanitary Authority.
S.F.D.A. Sale of Food and Drugs Act, 1875.
S.F.D. (B.) A. Sale of Food and Drugs Act, 1899.

Of these Acts, the Public Health Amendment Act, 1890, is alone "adoptive" at the discretion of a sanitary authority.

Local Sanitary Areas and Authorities.—The whole of England and Wales, outside the City of London, is divided into (*a*) administrative counties and (*b*) county boroughs. By the L.G.A., 1894, the administrative counties are divided into county districts, some of which are urban and others rural districts. For sanitary administration, the county boroughs are deemed to be urban districts, and, with the other urban districts, constitute urban sanitary districts; while the rural districts, each consisting of one or more parishes, are rural sanitary districts.

In every administrative county there is a county council, who may appoint one or more Medical Officers of Health, and who have various other powers and duties in connection with the sanitary administration and supervision of the county, more particularly of complaining under sec. 299 P.H.A., 1875, in cases where a S.A. is not doing its duty, and of enforcing the provisions of the Rivers Pollution Prevention Act, the Isolation Hospitals Acts, the Diseases of Animals Act, etc.

In county and other boroughs the mayor, aldermen, and burgesses, acting as the municipal council, are the urban sanitary authority. In urban districts, other than county and municipal boroughs, the district council constitutes the sanitary authority: but they may appoint committees, consisting either wholly or partly of their members, for the exercise of sanitary powers. An U.D.C. administers the P.H.A., 1875, the P.H.A. (Amend.) A., 1890, the P.H. (Water) A., 1878, if applied by the L.G.B., the R.P. Prev. A., the Factory Act, Housing of Working Classes Acts, the Inf. D.N. Act, the Inf. Dis. Prev. Act, 1890 (if adopted),

the S.F.D.A., the Horseflesh Act, the Margarine Act, the D.C.M. Orders, the Canal Boats Act, Infant Life Protection Act and Local Acts.

While in the provinces there is practically one S.A. acting for each district, it is otherwise in the Metropolis. Under L.G.A., 1899, with the exception of the City of London, every part of the administrative County of London is situated in some one of the metropolitan boroughs established under the Act. In the City and Port of London the City Corporation are the S.A. In the metropolitan boroughs the borough councils are the S.A., certain powers being transferred from the County Council. These powers can only be exercised within the borough, and refer chiefly to the registration of dairymen, to the removal of obstructions, and sky signs, etc. While certain powers of the County County will also be exercised by the borough councils.

Definitions.—There are certain definitions of terms in the various sanitary Acts which give to those terms meanings which are not the same as the common meaning. The more important of these definitions are the following:—

Building. This word includes wooden structures on wheels, also those without foundations, but resting simply on the ground. Under I.D.N.A., 1889, the term "building" applies to boats, vessels, ships, tents, vans, sheds, and other similar structures used for human habitation.

House. Though not absolutely defined, the term "house" is so extended as to include schools, factories, and other buildings in which persons are employed. For a structure to be a "house" it is not necessary that persons reside in it.

Owner. Under the Public Health Acts, the term "owner" means the person who, for the time being, receives the rack-rent of the lands or premises in connection with which the word is used, whether on his own account, or as agent or trustee for any other person, or who would so receive the same if such premises were let at rack-rent. By "rack-rent' is meant the rent that is not less than two-thirds of the full net annual value of the property.

Under Part II. Housing of the Working Classes Act, the owner of a property is held to be any person or corporation who has at least a twenty-one years' interest in it.

Drain means any drain of, and used for the drainage of, *one* building only, or premises within the same curtilage, and made merely for communicating therefrom with a cesspool, or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Sewers include sewers and drains of every description, except

drains to which the word "drain," as above defined, applies. In other words, a sewer is a drain receiving the drainage of two or more buildings, and may be an open channel, such as a polluted watercourse, as well as an underground culvert. Under the Metropolitan Local Management Act, 1862, this distinction between drain and sewer is not accepted, but a combined drain is deemed to remain a drain. So, again, in urban districts which have adopted the P.H. (Amend.) A., 1890, the interpretation of "drain" is different. Whereas, under P.H.A., 1875, if one or more houses drain into a common pipe, such common pipe or combined drain is a sewer: but under sec. 19 of the Amended Act, this common pipe is deemed to be a sewer only if all the houses belong to one owner; if they belong to more than one owner, then the combined drain is a drain repairable at the owner's expense, and not a sewer repairable at the expense of the S.A. Reference may be made to what has been said already upon this subject on p. 262.

Canal. Under the C.B.A., 1877 and 1884, the term "canal" includes any river, lake, water, or inland navigation "being within the body of a country, whether it is or is not within the ebb or flow of the tide."

Canal Boat. This includes any and every vessel, however propelled, used for conveyance of goods along a canal, as above defined, but does not include a ship registered under the Merchant Shipping Act, 1894, unless the L.G.B. orders otherwise, which it may do on the representation of a S.A., or any of its inspectors.

Bye-laws and Regulations.—In respect of certain matters, and under certain conditions expressly stated in the various Acts dealing with the Public Health, sanitary authorities may make bye-laws, having the force of law. These bye-laws are intended rather to supplement than to summarize, vary, or supersede the express provisions of the statute law. All bye-laws made by a S.A. under and for the purpose of the Public Health Acts must be under its common seal; and any such bye-law may be altered or repealed by a subsequent bye-law made pursuant to the provisions of the Acts. But no bye-law is of effect, if repugnant to the laws of England, or to the provisions of the Acts. A S.A. may, by any bye-laws made by it, impose such reasonable penalties as it thinks fit, not exceeding £5 for each offence, and, in the case of a continuing offence, a further penalty not exceeding 40*s.* per each day after written notice of the offence; but all such bye-laws imposing any penalty must be so framed as to allow of the recovery of any sum less than the full amount of the penalty. Bye-laws do not take effect unless and until they have been confirmed by the L.G.B., who have power to allow or disallow the

same as they think proper. The bye-laws, when confirmed, must be printed and hung up in the office of the S.A., and a copy of them must be delivered to any ratepayer of the district who applies for them (see P.H.A. 1875, secs. 182 to 185).

Some bye-laws must be made by a local authority; there are others which may be made by both urban and rural authorities, and others also which urban sanitary authorities alone are empowered to make. In the greater number, the power to make them is permissive.

Regulations differ somewhat from bye-laws, because with few exceptions they do not require the approval of the L.G.B. They may be simply passed as a resolution at a meeting of the authority, and may be amended or rescinded at a subsequent meeting. In certain cases, as, for instance, under sec. 125, P.H.A., 1875, relating to the removal to hospital of infected persons brought by ships, a regulation, just like a bye-law, has to be approved by a superior authority, and its breach involves liability to a money penalty.

Urban Sanitary authorities are empowered to make bye-laws, in respect of the following: —

Common Lodging Houses (P.H.A., 1875, sec. 80)
Cleansing and Scavenging (P.H.A., 1875. sec. 44).
Tenement Houses (P.H A., 1875, sec 90).
Seamen's Lodging Houses (M.S.A., 1894, sec. 214)
New Streets and Buildings (P.H.A., 1875, sec. 157, and Part III. P.H. (Amend.) A., 1890).
Slaughter-houses (P.H.A., 1875, sec. 169).
Markets and Fairs (P.H.A., 1875, sec. 167).
Offensive Trades (P.H.A., 1875, sec. 113).
Hop and Fruit Pickers (P.H.A., 1875, sec. 314, and P.H. (Fruit-pickers) A., 1882).
Tents and Vans (H.W.C.A., 1885, sec. 9).
Mortuaries and Cemeteries (P.H.A., 1875, sec. 141, and P.H. (Interments) A. 1879).
Open Spaces (P.H.A., 1875, sec. 164, and Open Spaces Act, 1887).

The Municipal Corporations Act, 1882, sec. 23, gives power to municipalities or borough councils to make bye-laws for the suppression and prevention of nuisances, not already punishable in a summary manner by any other Act in force throughout the borough. County councils have similar powers under the Local Government Act, 1888, sec. 16.

Urban authorities can further make bye-laws under the Housing of the Working Classes Act, 1890, for the regulation of all buildings provided under that Act or the Acts which it supersedes.

Rural sanitary authorities have similar powers for making bye-laws in respect of the following: (1) Private Scavenging; (2) Common Lodging-houses; (3) Tenement Houses and Seamen's Lodging-houses; (4) Hop and Fruit-pickers; (5) Tents and

Vans; (6) Mortuaries; and (7) Under the Housing of the Working Classes Act, 1890. Further, by adopting portions of the P.H. (Amend.) A., 1890, which are not expressly limited to urban districts, rural sanitary authorities can make certain bye-laws as to new and old buildings. The Local Government Board may confer on them any other powers as to bye-laws which the Public Health Acts give to urban authorities (P.H.A., 1875, sec. 276).

Every sanitary authority *must* make bye-laws as to common lodging-houses; every urban sanitary authority *must* do the same as to slaughter-houses; the exercise of power as to other bye-laws is optional.

The London County Council has power to make bye-laws for the regulation of the plans, levels, width, surface, inclination and materials of new streets and roads; for the plan and sites of buildings; as to the dimensions, form, construction, cleansing and repairing of pipes, drains and traps connected with sewers; and as to the construction, ventilation and cleansing of sewers (L.B.A., 1894, sec. 164, and certain unrepealed clauses of the Metropolitan Local Management Acts).

Also under the P.H. (Lond.) A., 1891, for regulating the conduct of offensive trades, and the structure of the premises (sec. 19). For prescribing the times for removal of any fæcal or offensive matter in or through London, so as to avoid the creation of a nuisance (sec. 16). As to the closing of cesspools and privies, the removal and disposal of refuse, and as to the duties of the occupier of any premises in connection with house refuse (idem). As to water-closets, earth-closets, ash-pits, cesspools, receptacles for dung, and the proper accessories thereof in connection with buildings (sec. 39). Also as to tenement houses (sec. 94). The power to make bye-laws under section 19 is permissive, but under secs. 16, 39, and 94 is compulsory. Under the L.G.A., 1899, it is the duty of each borough council to enforce the bye-laws and regulations in force for the time being.

The Metropolitan sanitary authorities, under the same Act, *must* make bye-laws for the control of nuisances arising from snow, ice, salt, dust, rubbish, ashes, carrion, fish, or filth in the streets; or from offensive matters running from any manufactory, brewery, slaughter-house, or dung-hill; for the prevention of keeping animals on any premises in such place or manner as to be a nuisance or dangerous to health; and as to the paving of yards and open spaces in connection with dwelling-houses (sec. 16). For the keeping of water-closets supplied with sufficient water for their effective action (sec. 39). For the cleansing and protecting of all cisterns, tanks, etc., used for storing water for domestic purposes, drinking, or the manufacture of beverages (sec. 50).

Similarly, in rural districts, the district council is the rural sanitary authority. Where the number of councillors of any such district are less than five, the L.G.B. may, by Order, nominate such number of persons as are necessary to make up that number from owners or occupiers of property situated in the district. The persons so nominated are entitled to act and vote as members of the rural S.A., but not further or otherwise. An alternative procedure is for the L.G.B. to order the affairs of the district to be administered by the district council of an adjoining district. Each rural district council has all the powers, duties, and liabilities, as a rural S.A., as were exercised by the old boards of guardians. They have also the same powers for appointing committees as have the district councils of urban districts other than boroughs (L.G.A., 1894, sec. 56).

The L.G.B. may, by a General Order, confer upon rural district councils such urban powers as they think fit; this is in addition to their right, under the P.H.A., 1875, to grant urban powers for particular areas, which right, under the 1894 Act, may be exercised by the Board on the application of the county or parish council concerned.

All district councils have the charge of highways. They also administer the Acts relating to petroleum and infant life protection, and the licensing of knackers' yards—a duty hitherto carried out by quarter sessions. In large rural districts, the district council may appoint parochial committees for outlying parishes to act as a resident subordinate authority, and as its agents. If such exist, the members of these committees must be selected from the members of the parish council. These parochial committees are completely under the control of the rural S.A., which made them, and have no jurisdiction beyond the places for which they are formed.

By the L.G.A., 1894, *parish councils* and *parish meetings* are constituted in rural districts. By sec. 8 of that Act, the parish council has power to utilize any well, spring, or stream within its parish, and power to drain, clean, cover, or remedy the condition of ponds and stagnant pools; also to acquire or hire land for allotments, make official representation to the district council under the Allotments Act; or to the M.O.H. under the Housing of the Working Classes Act, in regard to unhealthy areas and obstructive or unhealthy dwellings; or to the L.G.B., for granting of urban powers for their parish or any part of it. The district council may delegate to the parish council any powers which it may delegate to a parochial committee under the Public Health Acts. A parish council may complain to the county council if the rural district council have failed to provide or to maintain

sufficient drainage or water supply for the parish, or to enforce any provision of the P.H.A. 1875.

Apart from expenditure under adoptive Acts, such as the Public Health Amendment Act, 1890, the parish council must not incur expenses involving more than a *6d.* rate in any year, nor more than a *3d.* rate without the consent of the parish meeting. They may raise money on loan, but only with the approval of the parish meeting, the county council, and the L.G.B. The parish meeting has the exclusive power of adopting certain optional Acts, including the above-named, the Burial Acts, the Baths and Washhouses Acts, the Lighting and Watching Act, 1833, and the Public Improvements Act, 1860.

In order to simplify sanitary administration, boundaries of local sanitary areas are adjusted so as to prevent intersection of those which define counties, county districts, unions, and parishes. Small rural parishes are grouped into workable units for parish council purposes, but each has its own parish meeting. Although by the Act of 1894 some few sanitary powers are given to parish councils, those powers in no way derogate from the sanitary obligations of a district council, which is the true rural sanitary authority.

Although the powers conferred on urban and rural sanitary authorities are in many respects identical, they are not entirely so. By sec. 276, P.H.A., 1875, the L.G.B. may, on application of a rural S.A., or of persons rated to the relief of the poor, whose assessments amount to one-tenth of the nett rateable value of the district, declare, by Order, any provision of that Act in force in an urban district to be in force in such rural district or part thereof. In like manner the Private Street Works Act, 1892, and the P.H. (Amend) Act, 1890, may be put in force in the whole or part of any rural sanitary district. In amplification of the foregoing, by sec. 25 (7) of the L.G.A., 1894, similar powers may be exercised by the L.G.B., on application of a county council, or with respect to any parish or part thereof, on application of the parish council. Experience has shown that the provisions of the P.H.A., 1875, hitherto most frequently put in force, are secs. 42, 44, 157, and 158, relating to cleansing and watering of streets, and making of bye-laws as to nuisances and new buildings. Other sections which are occasionally put in force are 112 and 114, relating to offensive trades, and secs. 169, 170, which regulate slaughter-houses.

The same authorities *may* make bye-laws for the removal to hospital, or detention therein, of persons suffering from infectious disease (sec. 66). For preventing the fouling of tents, vans, sheds, and similar structures used for human habitation, and the spread of infectious disease by the inhabitants thereof (sec. 95). In

relation to tenement houses, under sec. 8 of H.W.C.A., 1885, these same authorities must also enforce any bye-laws made by the London County Council under secs. 16, 39, and 94 of the P.H. (Lond.) A., 1891.

In the City of London, similar powers are vested in the Corporation under the City of London Sewers Acts, 1848 and 1851, the Public Health (Lond.) Act, 1891, the Gardens in Towns Protection Act, 1863, the Metropolitan Open Spaces Act, 1877 and 1881, and the Open Spaces Act, 1887.

Under the Dairies Order, 1885 and 1899, any S.A. may make regulations for any of the following purposes: (*a*) for the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation, drainage, cleansing, and water supply of dairies, and cowsheds; (*c*) for prescribing precautions to be taken by purveyors of milk against infection; (*d*) for securing the cleanliness of milk-stores, milkshops, and milk vessels, used for containing milk for sale.

A S.A., subject to approval by the L.G.B., may make Regulations for the removal to hospital, and detention there as long as necessary, of all persons who may be brought within their district by either boat or ship, and who may be infected with an infectious disease (P.H.A., 1875, sec. 125). They have also power to make Regulations for the management of places provided by them for making post-mortem examinations ordered by a coroner (sec. 143).

The L.G.B. has power to make Regulations under secs. 130 and 134, P.H.A., 1875, in relation to cholera, and other dangerous infectious diseases.

From time to time, the L.G.B. has prepared and issued "model bye-laws" to serve as guides to sanitary authorities when seeking to frame bye-laws. As these models have been very generally adopted, subject to occasional modifications, by various local authorities, a summary of them will be given under their proper heading, where their provisions may help to a better appreciation of the requirements of the several Public Health Acts. The following have been issued up to the present time:—

Private Scavenging.
Prevention of Nuisances.
Common Lodging Houses.
New Streets and Buildings.
Markets.
Slaughter-houses.
Hackney Carriages.
Horses, etc., let for hire.
Pleasure-boats.
Pleasure-grounds.
Public Bathing.
Baths and Wash-houses.
Houses let in Lodgings.
Cemeteries.
Mortuaries.
Hop-pickers.
Offensive Trades, including those of a
- Blood-boiler.
- Bone-boiler.
- Fell-monger.
- Soap-boiler.
- Tallow-melter.
- Tripe-boiler.
- Blood-drier.
- Leather-dresser.
- Tanner.
- Fat-melter.
- Glue-maker.
- Size-maker.
- Gut-scraper.

Supplementary to these model bye-laws, various regulations in regard to the management of mortuaries and cemeteries have been issued by the Home Secretary.

Cleansing and Scavenging.—By sec. 42, P.H.A., 1875, every S.A. may, and when required by the L.G.B. shall undertake or contract for the removal of house refuse and cleansing of privies, ashpits, etc. Further, every urban S.A. and every rural S.A. invested by the L.G.B. with the requisite powers may, and when required by the Board shall themselves undertake or contract for the proper cleansing and watering of streets for the whole or any part of their district. All refuse, so collected, shall be the property of the local authority, to be sold or otherwise disposed of. Moreover, if Part III. P.H. (Amend.) A., 1890, has been adopted, the S.A. may, under sec. 26 (2) of that Act make bye-laws imposing on occupiers duties to facilitate the removal of refuse. Any person obstructing removal to be liable to a penalty not exceeding £5, except as regards refuse, etc., which the occupier intends to employ for his own use, unless he meanwhile suffers it to become a nuisance. If the S.A., having themselves undertaken or contracted for the removal of house refuse from premises, or the cleansing of earth-closets, privies, ashpits, and cesspools, neglect, without reasonable excuse, to remove any refuse within seven days of receiving a remonstrance from the occupier, they shall be liable to pay to him 5*s.* for each further day's neglect (sec. 43, P.H.A., 1875). An urban S.A. may, by sec. 45 of the same Act, provide receptacles and places for the temporary deposit of the matter collected.

By sec. 44, P.H.A., 1875, the S.A. has power to make bye-laws imposing the duty of cleansing footways, pavements, ashpits, privies, cesspools, and removing house refuse when they themselves do not contract or undertake to do the same, and may make bye-laws for the prevention of nuisances from accumulations of snow, filth, ashes, etc., and from the keeping of animals.

Model bye-laws have been issued by the L.G.B. for the prevention of these nuisances. (*a*) They require the house refuse to be removed once at least every week, and prescribe the same interval for the cleansing of every ashpit and privy, and every earth-closet furnished with a movable receptacle for fæcal matter, and with suitable means or apparatus for the frequent and effectual application of dry earth to such matter. Where the receptacle is fixed, the time allowed is three months, and a like period is prescribed for the cleansing of cesspools. (*b*) So far as nuisances from snow are concerned, the occupier of any premises must clear away snow from the footways and pavements adjoining his premises, as soon as possible after it ceases to fall. (*c*) The

refuse from any premises shall only be removed in a suitable covered receptacle or carriage, and if removed from premises within 20 yards of any dwelling, place of business, or public building, only between 7 a.m. and 9 a.m. from November to February, and between 6 a.m. and 8 a.m. from March to October. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed. (*d*) No load of filth must be deposited for more than 24 hours within 100 yards of any street, dwelling, public building, or place of business. Night soil deposited for agricultural purposes upon land within 100 yards of a street, dwelling, etc., and not deodorized, must at once be dug or ploughed into the ground. (*e*) Swine must not be kept within 100 feet of any dwelling, nor cattle where they can pollute water likely to be used for drinking, domestic, or dairy purposes, or for manufacturing drinks. The same prohibitions apply to the storage of dung. Premises wherein are kept any swine, cattle, horses, etc., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be water-tight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

If the M.O.H. or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing and purifying thereof would tend to prevent infectious disease, the S.A. may require the owner or occupier to cleanse, etc., and in his default may themselves do what is necessary (P.H.A., 1875, sec. 46).

Sec. 47 of the same Act prohibits not only keeping of swine in dwelling-houses so as to be a nuisance within an urban district, but also suffering stagnant water to lie in cellars or dwellings 24 hours after written notice from the S.A., and allowing contents of privies and cesspools to overflow or soak out, on a penalty not exceeding 40*s*., and a daily penalty not exceeding 5*s*. after notice, and authorizes the abatement of the nuisance by the S.A. at the occupier's expense. Moreover, a sanitary inspector in an urban district may give notice to the owner of any offensive accumulation of matter, or to the occupier of the premises whereon it exists, to have it removed within twenty-four hours, failing which the S.A. may remove the same (sec. 49). An urban authority may give public notice requiring the periodical removal of manure from mews, and other public premises, and enforce the same under penalty (sec. 50).

In cases where Part III. P.H. (Amend.) A., 1890, is in force,

by sec. 27 of the same, the S.A. has powers for keeping common courts and passages clean, apportioning the expenses incurred to the occupiers of adjacent premises.

In the Metropolis, the provisions for cleansing and scavenging under the P.H. (Lond.) A., 1891, are somewhat more stringent than those of the P.H.A., 1875, which controls the main actions of sanitary authorities in the provinces. By secs. 29 and 30 of the London Act, the S.A. *must* cleanse streets, footpaths, cesspits, earth-closets, and privies. They *must* remove house refuse at proper intervals, and trade refuse also, if required to do so, on payment. As to what is or is not *trade* refuse shall, on complaint of either party, be determined by a petty sessional court, such decision being final (sec. 33 (2)). The S.A., further, may undertake the collection of manure and other refuse, on request; or may by order, require periodical removals by owner (sec. 36).

Sec. 16 (2) of the London Act empowers the county council to make bye-laws (*a*) for prescribing the times for removal of fæcal or other offensive matter through London, and for providing that the vessel or carriage therefor is properly constructed so as to prevent any nuisance; and (*b*) as to the closing and filling of privies, removal of refuse generally, and as to the duties of the occupiers in relation to facilitating the removal of it by the scavengers of the S.A. Further, a constable may arrest without warrant and take before a justice any person found committing an offence against such bye-laws, and who refuses to give his true name and address. Swine may not be kept in London within forty yards of a street or public place, nor be allowed to stray into any public place. A court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose (sec. 17).

Sewers and Disposal of Sewage.—By the P.H.A., 1875 (sec. 13), it is enacted that all sewers, except certain private sewers, are vested in the S.A. of the district. The exceptions mentioned in the section are (1) Sewers made by a person or persons for his or their profit; (2) sewers made and used for draining or improving land under any local or private Act, or for irrigation; (3) sewers under any commissioners of sewers appointed by the Crown. The S.A. may purchase (sec. 14), or construct (sec. 15) sewers. They must provide such sewers as are necessary for effectually draining their district, having, by sec. 16, powers of taking them through, across, or under lands and streets. Sec. 308 of the Act provides for compensation for damage, to be ascertained by arbitration. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed

(sec. 19). The performance of these duties by a S.A. can be enforced on complaint by individuals (sec. 299), while further powers, in this respect, are given by secs. 16 and 19 of the L.G.A., 1894, to county councils, on complaint by a parish council of a defaulting rural sanitary authority.

Under sec. 7, Rivers Pollution Prevention Act, 1876, every S.A. must give facilities for factories to drain into sewers, but provision is given for the protection of sewers from injurious matters such as anything which may impede the flow of their contents, any chemical refuse, waste steam, or water or liquid heated above 110° F., by secs. 16 and 17, P.H. (Amend.) A., 1890. The restrictions imposed by secs. 32, 33, and 34 of the P.H.A., 1875, on the execution of sewerage works by a S.A. outside its own district, involve the giving of a public notice, and in case of objection, the work not to be commenced without sanction of the L.G.B., who may appoint an inspector to make inquiry and report.

For the protection of the sewers of an urban sanitary authority, sec. 26, P.H.A., 1875, provides a penalty for unauthorized buildings over them; and secs. 150 and 151 give power to the S.A. to compel the sewering of private streets, subject to any bye-laws the authority can get confirmed by the L.G.B. Powers are given by sec. 27 of the same Act for the treatment and disposal of sewage, but sec. 17 expressly insists that such disposal of sewage must not be into streams, unless purified before discharge; this latter section, however, needs to be read in connection with the Rivers Pollution Prevention Acts, 1876 and 1893, which give a certain amount of protection to sanitary authorities in respect of the pollution of streams and rivers by sewage channels used, constructed, or in process of construction at date of passing of the Act of 1876. Secs. 28, 29, and 30 of the P.H.A., 1875, further give power to the S.A. to deal with land appropriated to sewage purposes, to contribute to works executed by others for the disposal of the sewage, and to agree for communication of sewers with sewers of adjoining districts.

The incidence of the charge of sewage and other public sanitary works in urban districts is usually made by a general district or borough rate. In rural districts, the incidence of charge of expense of sewerage and other sanitary works are not made on the entire district, but constitute a separate charge on parishes or parts of parishes for which the works have been carried out, and the areas liable to contribute are termed "contributory places" (sec. 229). There are four kinds of contributory places: (1) a rural sanitary authority may, subject to approval by the L.G.B., constitute any portion of its area a "special drainage

district" for the purpose of charging thereon exclusively the expenses of sanitary works, the cost of which is not spread over the entire district, and thereupon such area becomes a "contributory place;" (2) where no part of a parish is situate in a special drainage district, or in an urban sanitary district, the entire parish is a contributory place; (3) where no part of a parish is in an urban sanitary district, but part of it is in a special drainage district, the part not in a special drainage district is a contributory place; (4) where part of a parish is in an urban sanitary district, and part in a rural sanitary district, so much of it as is not in an urban district or special drainage district is a contributory place (sec. 229).

In the Metropolis, outside the city, the county council, as the successors of the Metropolitan Board of Works, are the local authority for the purposes of the main sewerage and disposal of the sewage of London, while the borough councils are the local authorities for the purpose of the sewerage and drainage, other than the main sewerage. The powers of the late Metropolitan Board of Works, and consequently of their successors, the county council, as regards main sewerage are derived from the Metropolis Management Act, 1885, taken in conjunction with a similar Act of 1862, and the Metropolitan Main Drainage Act, 1858.

While the main sewers are to be constructed and kept so as not to be a nuisance, the county council has power to declare sewers to be main sewers, and to take jurisdiction over sewerage and drainage matters belonging to the boroughs, also to control the borough councils in the construction of sewers, etc., by means of bye-laws. The general powers of the London County Council in respect of sewerage and disposal of sewage are very similar to those of the sanitary authorities in the provinces under the P.H.A., 1875. As relates to procedures for the prevention of floods, the powers of the county council, by inheritance from the Metropolitan Board of Works, are derived from the Metropolitan Management (Thames River Prevention of Floods) Amendment Act, 1879. All sewers, etc., within the City are vested in the Corporation, who have full power over them and all drains communicating with the public sewers, under the City of London Sewers Act, 1848.

By the Metropolis Management Act, 1855, sec. 68, all sewers, other than those now vested in the county council and the City Corporation, are vested in the borough councils, who from time to time must repair, maintain, alter, or extend as may be necessary; but no new sewers can be made in the administrative county of London without the approval of the county council. The powers given by the above provisions are extended in certain

cases to areas outside the Metropolis by sec. 58 of the Metropolis Management Act, 1862. The Act of 1855 (secs. 73 to 75) further provides for the ventilation, trapping, cleansing, inspection, and proper connection of drains with sewers on the part of the sanitary authorities; while sec. 202 of the same Act gives the local authorities power to make bye-laws as to drains. For the purposes of their sewers, and for other purposes of the Metropolis Management Acts, every vestry or district board has the same power as the county council to purchase lands. These powers of purchase, however, are not compulsory (secs. 151, 152).

House Drainage, Water-Closets, Privies, etc.—Every sanitary authority, by secs. 22 to 25 P.H.A., 1875, has power to enforce drainage of undrained houses, and in certain cases to close existing drains on condition of providing others. These drains must lead to the public sewer if there be any within 100 feet of the site of the house; if not, to a covered cesspool in such position (not under a house) as the S.A. may direct. Failing compliance, the authority may carry out the work and recover in a summary manner the expenses incurred from the owner, or may by order declare the same to be "private improvement expenses." These private improvement expenses may be made payable by instalments with interest. They may, moreover, be levied on the occupier, whereas the expenses, if incurred summarily, will only be recoverable from the owner. It occasionally happens that owing to the delay in construction of sewers, houses have been supplied with cesspools and effectual drains leading thereto. In those cases the S.A. are under no obligation to pay the costs of drains necessary for enabling the house to discharge its sewage into the new sewers. Where the sewer is in the same sanitary district as that in which the premises are situate, the owner or occupier, upon giving due notice and complying with the regulations of the authority as to the mode in which the communication is to be made, is entitled to carry drains into the public sewer. In places where Part III. P.H. (Amendt.) A., 1890, has been adopted, by sec. 18 of that Act, the owner or occupier has a right to require the S.A. to make the communication at his cost. Where the sewer is in another sanitary district, the communication must be made on such terms and conditions as may be agreed upon between the owner or occupier and the S.A. to whom the sewer belongs.

Where any drain or cesspool is a nuisance, or injurious to health, the S.A. may take proceedings to remedy the matter either under sec. 41, P.H.A., 1875, or under the provisions of the same Act relating to nuisances (see p. 456). All the foregoing provisions apply to existing houses and drains without regard to the date of their construction, in both urban and rural districts.

In urban districts, and in rural districts, or contributory places endowed with urban powers by sec. 276, P.H.A., 1875, not only may *no* house be built, or rebuilt after having been pulled down to or below the ground floor, or be occupied after having been built or so rebuilt until proper covered drains have been constructed and duly connected with either a sewer or cesspool, as above indicated, to the satisfaction of the S.A. (P.H.A., 1875, sec. 25), but the authority may make bye-laws as to the mode in which connections between drains and sewers are to be made (sec. 157). This 157th section of the 1875 Act is only of limited extent, as it provides that no bye-law made under it shall affect any building erected in any place which, on August 11, 1875, was included in an urban sanitary district before the Local Government Acts came into force in such place, or any building erected in any place which, on that date, was not included in any urban sanitary district, before such place became constituted or included in an urban district, by virtue of any order of the L.G.B. subject to this enactment. Nor might any bye-law made under the section, apply to buildings belonging to railway companies, and used for the purposes of such railways under any Act of Parliament. In places where Part III. P.H. (Amend.) A., 1890, has been adopted, sec. 23 of this same Act has extended the operation of this 157th section of the 1875 Act to buildings erected before the time mentioned and to rural sanitary districts. Rural S.A.s can therefore now, by adopting this part of the 1890 Act, obtain these very important powers throughout their districts without the intervention of any order of the L.G.B.

The law relating to privies, water-closets, excrement and refuse disposal resembles that relating to house drainage inasmuch as it is contained partly in statutory enactments applicable to both urban and rural sanitary districts, and partly in bye-laws applicable only to urban districts and to those rural sanitary districts or contributory places to which it has been specially applied by order of the L.G.B. The general statutory enactments in regard to these matters of excrement and refuse disposal are contained in the P.H.A., 1875, secs. 35 to 45, and practically amount to the following :—

It is unlawful to erect any house without a sufficient water-closet, earth-closet or privy, and an ashpit with proper doors and coverings; and the same must be provided for any existing house on the order of the S.A., who may require a separate closet for each house (secs. 35, 36, 37). The S.A. may order sanitary conveniences in factories where persons of both sexes are employed (sec. 38), while the Coal Mines Regulation Act, 1887, sec. 74, makes the same provision applicable to parts of mines above

ground in which women and girls are employed. Every S.A. must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (P.H.A., 1875, sec. 40); while urban sanitary authorities may provide public urinals, closets, or receptacles for refuse (idem. 39–45). On the written application of any person that any drain, closet, ashpit, or cesspool is a nuisance, the S.A. may, by writing, empower their surveyor or inspector, after giving 24 hours' notice, to enter the premises and open the ground; if any defect is found, the S.A. must serve notice upon the owner or occupier to do the necessary work, but if there is no defect the authority must close the ground and make good any damage (P.H.A., 1875, sec. 41).

The Local Government Board have issued a series of model bye-laws relating to the various matters for which bye-laws may be made by a S.A. under the foregoing provisions. Their general provisions are sufficiently indicated in the following summary:—

Drainage.—Damp sites must be drained by earthenware field pipes properly laid to a suitable outfall, but not directly communicating with any sewer, or cesspool, or drain containing sewage. Rain pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest story must be such as to allow of the construction of a drain sufficient for the drainage of the building communicating with a sewer at a point above the centre of the sewer. All drains for sewage must be made of impervious pipes 4 inches or more in internal diameter, laid with a proper fall in a bed of concrete, and with water-tight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 inches thick all round, and must be laid at a depth below the surface at least equal to its diameter, and lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of the flow.

There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements:—(1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap. that is, as near

as possible to the head of the drain, vertically upwards in such manner and to such height (in no case less than 10 feet) as to prevent any escape of foul air into any building; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening near the ground level at the head of the drain. The ground-level opening must have a grating, with apertures equal in total area to the sectional area of the drain. The pipe or shaft at the other end of the drain (whether used as a soil-pipe or not) is required to have a sectional area equal to that of the drain, and in no case to be less than 4 inches; all bends and angles are to be avoided as far as practicable.

No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil-pipe must be at least 4 inches in diameter, must be placed outside the building, and must be continued upwards in full diameter without bends or angles, to such a height and such a point as to afford a safe outlet for sewer air. This height and point will usually be above the highest part of the roof of the building to which the soil-pipe is attached, and, where practicable, not less than 3 feet above any window within 20 feet measured in a straight line from the open end of such soil-pipe. There must be no trap between the soil-pipe and the drain to which it leads, nor in any part of the soil-pipe, except such as may be necessary in the construction of the water-closet. The waste-pipe from a slop sink must conform to the same requirements as a soil-pipe. The waste-pipe from any other sink, bath, or lavatory, the overflow-pipe from any cistern and from any "safe" under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall and must discharge in the open air over a channel leading to a trapped gully grating at least 18 inches distant.

Water-closets must have a window opening directly into the external air, and measuring 2 feet by 1 foot clear of the frame; and, in addition to the window, adequate means of constant ventilation by air-bricks, air-shafts, etc. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin; the basin must be made of non-absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to fall free of the sides directly into the water. "Containers" and "D traps" are forbidden.

Earth-closets are subject to the same conditions as water-closets

so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage; if fixed, its capacity must not be greater than may suffice for three months, nor in any case greater than 40 cubic feet, and it must in every part be 3 inches above the ground. In the case of earth-closets placed inside houses, the maximum limit of size may with advantage be reduced to 2 cubic feet.

Privies must not be erected within 6 feet of a dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging, without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top; the floor must be paved, and raised 6 inches above ground in all parts, with a fall of half an inch towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and raised 3 inches above the ground level, and all the sides of the said area must be made of flag, slate, or brick, at least 9 inches thick, and rendered in cement. If the receptacle is fixed, it must be in every part 3 inches above the ground level, and its capacity not exceeding 8 cubic feet, presuming that the scavenging will be done weekly: suitable means or apparatus must be provided in connection with the privy for the application of ashes, dust, or dry refuse to the filth deposited; and the receptacle must be so constructed that the contents may not at any time be exposed to rainfall or to the drainage of any waste water or liquid refuse from any adjoining premises, while at the same time conveniently accessible for scavenging; the materials and construction must be such as to prevent any absorption by any part of it of any filth deposited therein, or any escape by leakage or otherwise of its contents. It must in no way be connected with a drain.

Cesspools must not be constructed within 50 feet of any dwelling, public building, or place of business, nor within 100 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as to conveniently admit of scavenging

and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered over by an arch or otherwise, and adequately ventilated; they must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

Ash-pits must not be constructed within 6 feet of any dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, nor otherwise in such a position as to entail danger of the pollution of such water. Ash-pits must be so placed and constructed as to conveniently allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cubic feet, or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 inches thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 inches above the ground level. The ash-pit must be roofed and ventilated, and provided with a door so arranged as to allow of the convenient removal of the contents, and to allow also of being closed and fastened. The ash-pit must not be connected with any drain.

In the Metropolis, in regard to all the foregoing matters, the London County Council, by sec. 39 (1) of the P.H. (Lond.) A., 1891, are empowered to make bye-laws, which it is the duty of every S.A. in London outside the City to enforce and observe. Bye-laws made by the county council under this Act do not, however, extend to the City; but in that area analogous bye-laws can be made by the Corporation, who, as before stated, are the local authority. These bye-laws, whether made by the county council or by the City Corporation under the London Act of 1891, are subject to the provisions of secs. 182 to 185 of the P.H.A., 1875, as already explained in connection with bye-laws made by any S.A. in the provinces (see p. 435). In their main provisions the bye-laws in force in the administrative county of London and in the City accord closely with those suggested as models by the L.G.B.

The obligations and powers of a S.A. in London in relation to house drainage and the removal of refuse are very similar to those of a sanitary authority in other parts of the country. A new house *must* have "one or more water-closets, as circumstances may require," with proper water supply, trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the S.A. (P.H. (Lond.) A., sec. 37). A privy or earth-closet may only be substituted if the available

sewerage and water supply is insufficient for a water-closet. Any person who may think himself aggrieved by any notice or act of the S.A. may appeal to the county council, whose decision is final. These appeals are governed by sec. 126 of the London Act. Penalties are prescribed for (*a*) constructing or reconstructing water-closets, etc., not in accordance with this Act, or any bye-laws, or in defiance of notice or prohibition; (*b*) for discontinuing any such water supply without lawful authority; (*c*) illegally or wilfully injuring or constructing a drain or water-closet so as to create a nuisance or danger to health (sec. 41).

Water Supply.—Owing to the privileges granted, from time to time, to companies and other corporate bodies, sanitary authorities are under certain restrictions as to their supplying water. Where a water company has parliamentary powers to supply water over any given area, the S.A. must give notice to the company stating the purposes for which and extent to which it requires water; and if the company are able and willing to supply sufficient and proper water for the purposes of the local authority, this latter body may not construct any water-works within that area (P.H.A., 1875, sec. 52). Moreover, sec. 332 of the Act provides that when the supply of water must be taken from a running stream, the S.A. before abstracting water from such stream, river, or source, must obtain the consent in writing of any person or persons who have prior claims upon those streams or sources.

When not hampered by either of the foregoing restrictions, any S.A. may construct works for supplying any part of their district with water, or may take on lease, hire, or purchase works (with the sanction of the L.G.B.), or contract for the supply (P.H.A., 1875, sec. 51). When a S.A. supply water within their district, they have the same powers and are under the same restrictions for carrying their mains within and without their district as they have and are subject to in respect of their sewers (sec. 54). The water supplied must be pure and wholesome, and under sufficient pressure as will carry the same to the top storey of the highest dwelling-house in the district supplied. There is, however, no obligation to provide a constant supply under pressure (sec. 55). The S.A. have power to charge water-rates and rents in respect of premises to which they supply water, while all public cisterns, pumps, wells, etc., used for the gratuitous supply of water to the inhabitants of a district, vest in and are under the control of such authority (secs. 56 and 64).

The same Act (sec. 62) gives any S.A. power to require houses which are without a proper water supply to be so supplied, if it can be furnished at a cost not exceeding the water-rate authorized by any local Act or twopence per week, or such other cost as the

L.G.B. may, upon application, determine to be reasonable. In order to guard against the pollution of sources of water supply, the S.A. have power to proceed against offenders (secs. 67 and 69). If the water of any well or cistern is deemed to be injurious to health, a justice's order may be obtained for its being permanently or temporarily closed, or the water to be used for certain purposes only, and for the payment of any necessary analysis of the sample at the cost of the S.A. (sec. 70).

The general provisions of the P.H.A., 1875, in respect of water supply may be briefly summarized by saying that it is the duty of the S.A. to provide their district with water, where danger exists to the health of the inhabitants from either the unwholesomeness or the insufficiency of the existing supply, and a proper supply can be got at reasonable cost. If the S.A. neglect to do this duty, the same proceedings can be taken to make them perform it under sec. 299 of the Act of 1875, or, if they are a rural sanitary authority, under the L.G.A., 1894, secs. 16 and 19, just as can be taken in the case of their failing to supply the district with sewers. But cases arise where it is impossible for the S.A. to supply water at a reasonable cost; under these circumstances they may require the owner to do so, if he can at reasonable cost (P.H. (Water) A., 1878, sec. 3). If neither the S.A. nor the owner can provide water at a reasonable cost, then, if the absence of a proper water supply creates a nuisance that the house is unfit for habitation, steps may be taken to obtain a justice's order prohibiting its being so used for human habitation (P.H.A., 1875, sec. 97).

It was largely to meet difficulties of this kind, especially in rural districts, that the P.H. (Water) A. of 1878 was designed. It applies to every rural sanitary authority, and also to such urban authorities as the L.G.B. may order (sec. 11). Under sec. 3 of this same Act, it is the duty of the local authority to provide or require the provision of sufficient water supply to every occupied dwelling-house within their district. From time to time they may take steps, by means of inspections on the part of their officers, to see that these conditions are fulfilled. The same powers of entry upon premises are given as are conferred by secs. 102 and 103, P.H.A., 1875, in respect of nuisances (sec. 7); and if the M.O.H. reports that an occupied house is without a proper water supply, and the S.A. are of opinion that such a supply can be provided at a reasonable cost (the interest on which at 5 per cent. shall not exceed twopence a week, or as the L.G.B. may, on the application of the S.A., decide to be reasonable in the circumstances), the S.A. may require the owner, subject to appeal to the L.G.B., to provide

such supply within a specified time, and in case of default may themselves carry out the necessary works at his expense. The authority may, on cause being shown why the requirements of the notice served by them should not be complied with, withdraw the notice or modify the terms thereof. Nothing, however, in this Water Act must be deemed to relieve the S.A. from the duty imposed upon them by the P.H.A., 1875, of providing their district or any contributory part of it with a supply of water, where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at a reasonable cost (secs. 3 and 4).

In order to prevent houses being built in situations where they cannot be provided with water, the Water Act, 1878, has prohibited (sec. 6) the owner of any dwelling in a rural district that may be erected or rebuilt from the ground floor after July 4, 1878, from permitting such house to be occupied without a certificate from the S.A. that it is provided with a sufficient and available supply of wholesome water; such certificate to be based upon the report of the M.O.H. or sanitary inspector. Sec. 9 of the same Act provides that if the S.A. furnish a stand-pipe for water supply, they may make water-charges upon every dwelling within 280 feet, just as if the supply were actually given on the premises; but they may not make this levy upon houses which have a good supply within reasonable distance, from another source, unless the water from the stand-pipe is used by the inmates.

The L.G.A., 1894, sec. 8 (1) (*e*), empowers a parish council to utilize any well, spring, or stream within the parish, and to provide facilities for obtaining water therefrom, consistent with the just rights of any person or corporation; but these powers do not in any way derogate from the obligations of a rural sanitary authority in respect of supplying water.

Under the Rivers Pollution Prevention Act, 1876, proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or aggrieved local authority (sec. 8); but in respect of manufacturing or mining effluents, a S.A. only can take action, and that subject to the approval of the L.G.B. The Board, in giving or withholding consent, must have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by a S.A. of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and

that no material injury to the interests of such industry will be caused by the proceedings (sec. 6).

The water supply of the Metropolis is now in the hands of the Metropolitan Water Board. This Board controls the water supply not only in London, but also over a large extra-metropolitan area. Practically the Board has the same position as the provincial water companies, and so far as this question is concerned neither the county council nor any other local authority in London has any direct power. The controlling authority, as affecting the public health, over the water board is the L.G.B., who have the water supplied examined periodically, approve or disapprove of new sources of supply, of various regulations made by the board for preventing waste, misuse, or contamination, and who also inquire into complaints made to them as to the quality or quantity of the water supplied for domestic use.

The Metropolis Water Act gives the County Council power to ask for the repeal or alteration of any of the regulations for the above purposes, and if the board refuse to do so, to appeal to the L.G.B., who, on inquiry and report of some impartial engineer or person of engineering knowledge, may make such repeal or alterations as they think fit. The same Act contains similar provisions as to the county council asking for a constant supply in any given district. The board cannot, however, be compelled to give a constant supply to any premises in any district until its regulations, as approved by the L.G.B., are in operation in the district, nor if the board can show that at any time after two months from the date of the service of any requisition for a constant supply more than one fifth of the premises in the district are not supplied with the prescribed fittings. The county council have power to supply the prescribed fittings on default of owner or occupier. The L.G.B. have power to order a constant supply without application from the county council where they think that by reason of the insufficiency of the existing supply in the district, or the unwholesomeness of such water in consequence of its being improperly stored, the health of the inhabitants is, or is likely to be, prejudicially affected.

So far as relates to the powers of the metropolitan boroughs and borough councils in connection with the water supply, the P.H. (Lond.) A., 1891, indicates the absence of a proper water supply or of proper fittings in a house, to render such house unfit for habitation. A new house must not be occupied until the S.A. grant a certificate that it has a proper water supply (sec. 48). The water board cutting off the supply of water to any house, must give immediate notice to the S.A. (sec. 49). For the closure of polluted wells, etc., the S.A. have only to satisfy a justice that the

water is "so polluted or likely to be so polluted, as to be injurious or dangerous to health" (sec. 54). It must be noted that this section gives a S.A. somewhat greater powers than sec. 70, P.H.A., 1875, inasmuch as it says not only when the water is so polluted as to be injurious to health, but when it is so polluted *or likely to be so polluted* as to be injurious *or dangerous* to health. Moreover, it gives the court no power to allow the water to be used for certain purposes only, and imposes a fine not exceeding £20 for disobedience to any order under this section.

Every S.A. under the London Act of 1891 must make bye-laws for cleansing tanks, cisterns, and other receptacles for storing water likely to be used for drinking or domestic purposes, and guarding them from pollution (sec. 50). The model bye-laws framed by the L.G.B. in connection with this section, demand: (1) the emptying and cleansing of cisterns and tanks once at least in every six months, and at such other times as may be necessary to keep them clean; (2) every such tank, cistern, or receptacle to be fitted with a proper cover, and to be kept at all times properly covered. In cases where two or more tenants of a premises are entitled to the common use of any tank, cistern, or receptacle to which this bye-law applies, the foregoing requirements apply to the owner instead of to the occupier of the premises.

Nuisances.– In a legal sense, nuisances are of two chief kinds, namely, (1) nuisances at common law, (2) nuisances under the Public Health Acts, commonly called "statutory nuisances."

Statutory nuisances have been well defined by Wynter-Blyth as being "something which either actually injures, or is likely to injure health, and admits of a remedy, either by the individual whose act or omission causes the nuisance, or by the local authority." In the Public Health Act sense, as now understood and interpreted, the idea of a nuisance embraces future as well as present consequences. The sanitary law in respect of nuisances may be summarized in the following manner.

The provisions of the P.H.A., 1875, secs. 91 to 111, dealing with nuisances, apply to every urban and rural sanitary district, and are "deemed to be in addition to, and not to abridge any right, remedy, or proceeding under any other provisions of the Act, or under any other Act, or at law or in equity." But no person may be punished for the same offence both under these provisions and under any other law or enactment. Under this 1875 Act "nuisance" is regarded as likely to arise in connection with: (*a*) sewers, secs. 18, 19; (*b*) sewage, sec. 27; (*c*) construction of drains, closets, ash-pits, and cesspools, secs. 40, 41; (*d*) in connection with snow, dust, ashes, filth, and rubbish,

sec. 44; (*e*) swine, pigsties, and stagnant water in cellars, or the overflowing of privies and cesspools, sec. 47; (*f*) offensive trades, secs. 112, 113, and 114.

In regard to some of these cases, remedies are given by other provisions of the Act, more particularly by secs. 41, 49, and 50. It will rest with a S.A. to determine under which provisions they will proceed. The main section dealing with nuisances is, however, sec. 91, which defines the following to be nuisances to be dealt with summarily under the Act: (1) Any premises, including buildings and lands, in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, watercourse, privy, urinal, cesspool, drain, or ash-pit, so foul, or in such a state as to be a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or deposit which is a nuisance or injurious to health. (5) Any house, or part of a house, so overcrowded as to be dangerous or injurious to health of the inmates, whether or not members of the same family. (6) Any factory, workshop, or work-place, not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours, dust, or other impurities generated in the course of the work carried on therein that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein. (7) Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever; and any chimney (not being the chimney of a private dwelling house) sending forth black smoke in such quantity as to be a nuisance.

In defining these nuisances, the same section, however, provides that there is no penalty if the accumulation or deposit mentioned in (4) is necessary for, and has not been kept longer than is necessary for the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health. The provisions of sub-section (6) apply to all buildings, including schools, factories, and workshops, except such as are subject to the special provisions, relating to cleanliness, ventilation, or overcrowding, of the Factories and Workshops Acts. In respect of (7), there is no penalty if the Court is satisfied that the fireplace or furnace is constructed in such manner as to consume, as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended by the person in charge thereof. Under

the smoke sections, it is not necessary in taking action to prove anything with regard to health, it being sufficient to prove that on such and such a day and hour the chimney emitted *black* smoke. Urban sanitary authorities have some other powers with regard to smoke under sec. 171 of this Act, and under the Railway Regulation Act, 1868, and the Highways and Locomotives Act of 1878.

For interpreting the term "overcrowded" in sec. 91 (5), P.H.A., 1875, a sanitary officer usually takes as his guide the minimum standards laid down by the L.G.B. in their model bye-laws, namely, 400 cubic feet for rooms in which persons both live and sleep, and 300 cubic feet for rooms used solely for the waking life of the tenants. For factories and workshops, by the F.W.A., 1895 and 1901, overcrowding is deemed to exist when the cubic space for adults is less than 250 cubic feet, and 400 cubic feet during overtime. In the event of a second conviction for over-crowding within three months, the Court may order the closing of the premises (P.H.A., 1875, sec. 109). Another point to be noted in connection with sec. 91 (5) of the 1875 Act, is that the words "tent, van, shed, or similar structure" may be included within it by sec. 9 of the Housing of the Working Classes Act, 1885.

Unfenced quarries and abandoned coal-mines are deemed to be nuisances under sec. 91, P.H.A., 1875, by the Quarry Fencing Act, 1887, and by the Coal Mines Regulation Act, 1887.

It is the duty of every S.A. to cause their district to be inspected for the detection of nuisances, and to enforce the provisions of the P.H.A., 1875, in order to abate the same (sec. 92), but the authority may be put in motion by any aggrieved person, or by any two inhabitants of such district, or by any officer of the S.A., or by the relieving officer, or by any police officer (sec. 93). If satisfied of the existence of a nuisance, the S.A. is required by the Act to serve a notice on the person responsible, or, if he cannot be found, on the owner or occupier of the premises on which the nuisance arises, requiring him to abate the same within a time to be specified in the notice, and to execute such works as are specified in the notice to be necessary. When the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier, the notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier is not responsible for its occurrence, the S.A. may themselves abate the same without further order (sec. 94). On non-compliance with the notice, or if the nuisance, although abated, is likely to recur, the S.A. may apply to a justice, who must thereupon summon the person responsible to appear before a court of summary

jurisdiction (sec. 95). If the Court is satisfied that the alleged nuisance exists, or that although abated, it is likely to recur on the same premises, it must make an order requiring him to comply with the notice, or prohibiting the recurrence of the nuisance, and directing the execution of any necessary works. The Court may further impose a penalty not exceeding £5 (sec. 96). Where the nuisance is such as to render the house unfit for habitation, the Court may order the house to be closed, and may cancel this by a further order when satisfied that the house has been made fit for habitation (sec. 97). Any person not obeying the order of the Court, or failing to use diligence, is liable to a penalty not exceeding ten shillings per day during his default, and the S.A. may carry out the order and charge him with the expenses (sec. 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be carried out by the S.A.; and any matter or thing removed by the authority in abating any nuisance may be sold (secs. 100, 101). Where any nuisance under the Act is caused by the acts or defaults of two or more persons, the S.A. may institute proceedings against any one or more of such persons (sec. 255). Where a nuisance within a district is caused by some act or default beyond its limits, the S.A. may institute proceedings provided that they be taken before a court having jurisdiction in the district where the act or default is alleged to be committed or take place (sec. 108).

For the purpose of the provisions of this Act of 1875, relating not only to nuisances, but also for infectious diseases and hospitals, any ship or vessel lying in any water within the district of a sanitary authority is subject to their jurisdiction, as if it were a house. If in any other water, it is deemed to be within such district as the L.G.B. may prescribe, and in the absence of any such prescription, then within the nearest sanitary district (sec. 110). The master or other officer in charge of any such ship will be deemed to be the occupier; but these provisions do not apply to any of His Majesty's ships, or to those of any foreign government.

The S.A. and their officers have rights of entry between 9 a.m. and 6 p.m. upon private premises, and in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission is refused, a justice's order may be obtained (secs. 102, 103).

Where sanitary authorities fail to take proceedings for abatement of nuisances, individuals may obtain a remedy in one of three ways, either (1) by complaining to the L.G.B., who may issue an order, enforceable by mandamus in a High Court (sec. 299); or (2) on it being proved to the satisfaction of the L.G.B.

that a S.A. has made default in relation to nuisances under the P.H.A., 1875, that Board may authorize any police officer, acting within the district of the defaulting authority, to institute proceedings, which the defaulting authority might institute with regard to such nuisance (sec. 106); or (3) an individual may complain direct to a justice as to the existence of a nuisance, and the Court may make orders, penalties for disobedience of orders, etc., as in the case of a complaint relating to a nuisance made to a justice by a S.A. (sec. 105). This latter mode of procedure is obviously the most expeditious for any individual to take where he feels aggrieved by the neglect of a S.A. to take proceedings, and where the existence of a nuisance within the meaning of the Act is clear.

Under the P.H. (Lond.) A., 1891, and the L.G.A., 1899, the powers and duties of the borough councils in the capacity of sanitary authorities in London, with respect to nuisances, correspond in the main with those already detailed as applicable to sanitary authorities in England and Wales under the Act of 1875. The London Act embodies, however, several amendments and extensions of the law which have materially strengthened the hands of the Metropolitan sanitary authorities for dealing with nuisances. Sec. 2 of the London Act extends the definition of "nuisance," making it include not only that which is *injurious* to health, but also that which is *dangerous* to health. It also makes it include any cistern, water-closet, earth-closet, or dung-pit, so foul or in such a state as to be a nuisance or injurious, or dangerous to health, and any such absence from premises of water fittings as is a nuisance by virtue of sec. 3 of the Metropolitan Water Act, 1871. Further, *any person* may give information to the S.A. of a nuisance, and it is the *duty* of every officer of the authority and of the relieving officer so to do, and to give written notice to the persons who may be required to abate it.

In giving notice requiring abatement of a nuisance, it is optional to specify the works to be executed; also, where the person responsible for causing the nuisance cannot be found, the S.A. may not only themselves abate the nuisance, but also do what is necessary to prevent its recurrence. In cases of overcrowding, the S.A. must take proceedings to abate the nuisance. The penalty for wilful nuisance or non-abatement is a fine of £10 for each offence, whether an order to abate it or prohibiting its recurrence is made or not (P.H. (Lond.) A., 1891, sec 4).

Similarly, the maximum fines for failing to comply with an order for the abatement of a nuisance, or for acting contrary to a prohibition order, are increased from the amounts fixed by the P.H.A., 1875, to 20*s.* a day, and 40*s.* a day respectively, during

default or contrary action, as the case may be (sec. 5 (9)). Wilful damage to drains, water-closets, etc., so as to create nuisances, involve a fine not exceeding £5 (sec. 15). Groundless appeals to quarter sessions against nuisance orders are checked by daily fines of 20*s*. (sec. 6 (3) (4)).

The S.A., moreover, is required by sec. 16 of the London Act to make bye-laws for the prevention of nuisances arising from (1) any snow, ice, salt, dust, ashes, rubbish, offal, carrion, fish, filth, or other matter in the street; (2) from any offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or fishmonger's shop, or dunghill, into any uncovered place, whether or not surrounded by a wall or fence; (3) from keeping of animals; (4) as to the paving of yards and open spaces in connection with dwelling-houses. It is, moreover, the duty of the S.A. to enforce any bye-laws made, in respect of these matters, by the county council.

Under the L.G.A. (Lond.), 1899, it is the duty of each borough council to enforce within their borough the bye-laws and regulations for the time being in force with respect to dairies and milk, and with respect to slaughter-houses, knackers' yards, and offensive businesses, and for the purpose of performing this duty, the borough council shall in all cases have the same powers of entry as was accorded under the P.H.A. (Lond.), 1891.

As regards the prevention of smoke in London, sec. 24, P.H. (Lond.) A., 1891, corresponds closely with sec. 91 of the 1875 Act; but the main provisions against nuisances arising from smoke in the Metropolis are contained in sec. 23 of the London Act, which provides that "every furnace employed in the working of engines by steam, and every furnace employed in any public bath or wash-house, or in any mill, factory, printing-house, dye-house, iron-foundry, glass-house, distillery, brew-house, sugar-refinery, bake-house, gasworks, waterworks, or other building used for the purpose of trade or manufacture (although a steam-engine be not used or employed therein), shall be constructed so as to consume and burn the smoke arising from such furnace." Sanitary authorities must carry out these provisions of this section, and, moreover, any information under it is not to be laid except under the direction of a S.A. This section extends to the port of London, where it must be enforced by the port sanitary authority, which is the City Corporation.

Unsound Food.—Under the P.H.A., 1875, the M.O.H. and inspector of nuisances have power, at all reasonable times, including Sundays, to examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk exposed for sale, or deposited for the purposes of sale, or of preparation for

sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate (sec. 116), who may order it to be destroyed or so disposed of as to prevent it from being exposed for sale, or used for the food of man, and inflict a penalty not exceeding £20, or a term of imprisonment of not more than three months (sec. 117). The proof that it was not intended for the food of man rests with the person charged. Any person hindering these officers from inspecting meat, etc., is subject to a penalty of £5 (sec. 118). On complaint made by oath by any officer of a S.A. that there is reason to believe that there is kept or concealed on any premises any articles to which these sections apply, a justice may grant a search-warrant, and any person hindering the execution of this warrant is liable to a penalty of £20 (sec. 119).

Under sec. 4, S.F.D.A., 1899, the Board of Agriculture has the power to fix the limit of deficiency from the normal in the composition of milk, cream, butter, and cheese, and declare what addition of extraneous matter thereto, or proportion of water therein (including, as to the former, condensed milk), shall raise a presumption that the article in question is not genuine, or is injurious to health. Statutory orders under this section have been issued, and have now the force of law (see p. 168).

Proceedings for offences under the various Acts will have to be taken in all cases within twenty-eight days from the date of purchase; the summons is to state the nature of the offence with which the defendant is charged, and to be accompanied by a copy of the analyst's certificate, and is not returnable for hearing until after the expiration of fourteen days from the date of service (sec. 19).

In markets and fairs under the control of a S.A., the sale of unwholesome meat or provisions is subject to similar provisions under sec. 15 of the Markets and Fairs Clauses Act, 1847, which is incorporated with the P.H.A., 1875. Where the market or fair does not belong to the local authority, the above provisions will not apply, unless a local Act is in force, with which the Market and Fairs Clauses Act is incorporated. A S.A. can make bye-laws for preventing the sale of unwholesome provisions in a market or fair by sec. 42 of the Act of 1847, also incorporated in the P.H.A., 1875, but owing to the stringency of secs. 116 to 119 of this latter Act, these bye-laws will be rarely necessary.

In the Metropolis, under sec. 47, P.H. (Lond.) A., 1891, the provisions as to the sale of unsound food are somewhat more stringent. The London Act not only closely follows the lines of sec. 28, Part III., P.H. (Amend.) A., 1890, but renders the offender liable, on conviction, to a fine not exceeding £50, or

imprisonment for six months with or without hard labour. The section further enforces the liability of the previous vendor of the food, and also renders any one obstructing an officer acting under a warrant for entry within twelve months after a previous conviction for obstruction or evidently with intent to prevent detection, liable to imprisonment for a month in lieu of fine. The S.A. have further the duty placed upon them of removing unsound food, as if it were trade refuse, on the receipt of written notice from a person having possession of the same.

Horseflesh.—The provisions controlling the sale of horseflesh for human food are the same in all parts of the United Kingdom. They are contained in the Sale of Horseflesh, etc., Regulation Act, 1889, which defines "horseflesh" to be horseflesh, cooked or uncooked, alone or mixed with other substances, and includes the flesh of asses and mules.

This Act provides that the flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed in conspicuous and legible characters, 4 inches long, an announcement that horseflesh is sold there. If otherwise, the M.O.H. or inspector of nuisances, or any other officer of the S.A., may seize the meat and carry it before a magistrate, who may order as to its disposal as he thinks fit; and the offender is liable to penalty. It is illegal to supply horseflesh for human food to a purchaser asking for other meat, or for a compound article not usually made of horseflesh.

Bakehouses.—Under the Factory and Workshop Act, 1901, considerable powers of sanitary control are given to district councils over bakehouses. Sec. 97 prescribes the sanitary regulations for bakehouses; sec. 98 imposes a penalty for a bakehouse being unfit for the purpose on sanitary grounds; secs. 99 and 100 provide for the periodical limewashing, painting, etc., of these places, and require proper regulation of sleeping accommodation near bakehouses; sec. 101 prohibits underground bakehouses except where they were so used at the passing of the Act, and subject to the foregoing provision, after the first day of January, 1904, no underground bakehouse shall be used unless certified by the district council to be suitable as regards construction, light, ventilation, and in all other repects. Sec. 102 imposes on the district council the duty of enforcing these provisions as to bakehouses.

Milk Supplies.—It has already been shown that, under sec. 117, P.H.A., 1875, and under sec. 15, Market and Fairs Clauses Act, 1847, unwholesome provisions, including milk, may be dealt with by seizure and condemnation. The Acts, however, which are most active in regulating the milk supply, are the C.D.

(Animals) A., 1878 and 1886. Under these Acts the L.G.B. have power to make general or special orders for (1) the registration with the local authority of all persons carrying on the trade of cowkeepers, dairymen, or purveyors of milk; (2) for the inspection of cattle in dairies, and the general sanitation of dairies and cowsheds; (3) for securing the cleanliness of milk-stores, shops, and vessels for containing milk; (4) for guarding milk against infection; (5) and for authorizing local authorities to make regulations for any or all of the aforesaid purposes.

Under the powers thus conferred, the L.G.B. issued the Dairies, Cowsheds, and Milk-shops Orders of 1885, 1886, and 1899, the chief effect of which Orders is to throw upon every S.A. the duty of supervising the milk trade in their district, and of carrying out certain general regulations prescribed by the Orders. These duties are common to all districts, but any S.A. may arm itself with further powers by making regulations under sec. 13 of the Order of 1885, having the force of bye-laws. The chief provisions of the Order of 1885, as amended by that of 1886, are summarized as follows:—

Section 6. (1) It shall not be lawful for any person to carry on in the district of any local authority the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as such in accordance with this article. (2) Every S.A. shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The S.A. shall register every such person, but the fact of such registration shall not be deemed to authorize such person to occupy as a dairy or cowshed any particular building, or in any way preclude any proceedings being taken against him. (4) The S.A. shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neigbours for their accommodation need not, by reason thereof, be registered.

Section 7. (1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order until provision is made, to the reasonable satisfaction of the S.A., for the lighting and ventilation, including air-space (800 cubic feet per head are suggested as a minimum), and the cleansing, drainage, and water supply; (2) or without giving one month's notice in writing to the sanitary authority.

Section 8. It shall not be lawful for any . . . cowkeeper or dairyman to occupy as a dairy or cowshed any building, the lighting

and ventilation, including air-space, and the cleansing, drainage, and water supply thereof, are not such as are necessary or proper for the health and good condition of the cattle therein; and for the cleanliness of milk vessels used therein for containing milk for sale; and for the protection of the milk therein against infection or contamination.

Section 9. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk or occupier of a milk shop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . . . so far as regards the production, distribution, or storage of milk; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of the trade as far as regards the production, storage, and distribution of milk; until in each case, all danger therefrom of the communication of infection to the milk, or of its contamination has ceased.

Section 10. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk, or occupier of a milk-shop or milk-store, after the receipt of notice of not less than one month from the local authority calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or room used as a milk-store or milk-shop.

Section 11. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk, or occupier of a milk-shop or milk-store, to use a milk-shop or store in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk-store or shop, and of the milk vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk to keep any swine in any building used by him for keeping cows, or in any milk-store or other place used by him for keeping milk for sale.

Section 13. Any S.A. may from time to time make regulations for the following purposes, or any of them :—(*a*) For the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water-supply of dairies and cowsheds; (*c*) for securing the cleanliness of milk-stores, milk-shops, and milk-vessels used for containing milk for sale; (*d*) for prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14. The following provisions shall apply to regulations made by any S.A. under this Order:—(1) Every regulation shall be published by advertisement in a newspaper circulating in the district of the S.A. (2) The S.A. shall send to the L.G.B. a copy of every regulation made by them not less than one month before the date named for such regulation to come into force. (3) If at any time the L.G.B. are satisfied on inquiry, with respect to any regulation, that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.

Section 15. The milk of a cow suffering from *cattle-plague*, *pleuro-pneumonia*, or *foot-and-mouth disease* (*a*) shall not be mixed with other milk; and (*b*) shall not be sold or used for human food; and (*c*) shall not be sold or used for food of animals, unless it has been boiled.

The Amending Order of 1886 imposed penalties of £5 for every offence, and in the case of continuing offences, an additional daily penalty of 40*s*. The courts have power to reduce these penalties if they think fit.

For the purpose of enforcing orders made under the C.D. (Animals) A., 1878–1886, the S.A. and its officers have the same right of entry as they have under P.H.A., 1875, sec. 102, in respect of nuisances.

As regards the metropolis, the P.H. (Lond.) A., 1891, which repeals, so far as they apply to London, sec. 34 of the C.D. (Animals) A., 1878, and sec. 9 of the 1886 Act, gives the same powers as are given by those sections to sanitary authorities in the provinces, to the county council and the Corporation of London to make bye-laws applicable to so much of the administrative county of London as is not included in the City, and in the City respectively. The powers of the L.G.B. to make regulations and orders for dairies are the same in the Metropolis as elsewhere in England and Wales.

It is a pity that the Dairies, Cowsheds, and Milk-shop Orders are not more seriously enforced by S.A.'s; the custom of combining the duties of inspecting dairies, etc., with that of work under the C.D. (Animal) Acts, and employing policemen for these duties gives unsatisfactory results. Further, milk-sellers should be compelled to put notice boards or other information as to their registration over their doors. Another defect is the vagueness as to what is "disease" among cattle under the C.D. (Animals) Act, 1878: no mention is made of tuberculosis, an inclusion of which is very necessary. Reference may be made to remarks on this subject on p. 169.

Adulteration of Food.—The legislative enactments relating to this matter, in respect of the whole United Kingdom, are contained in the Sale of Food and Drugs Act, 1875, the Sale of Food and Drugs Act Amendment Act, 1879, the Margarine Act, 1887, the Sale of Food and Drugs Act, 1899, and, so far as concerns England and Wales, also the Local Government Act, 1888.

The S.F.D.A., 1899, defines "food" as including every article used for food or drink by man, other than drugs or water, and any article which ordinarily enters into or is used in the composition or preparation of human food, and shall also include flavouring matters and condiments; and "drug" as including medicine for external as well as internal use. The S.F.D.A., 1875 (sec. 2), enacts that "no person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any article so mixed, coloured, stained, or powdered . . ." (sec. 3). "No person shall, except for the purpose of compounding, . . . mix, colour, stain, or powder (or permit any other person to mix, colour, stain, or powder) any drug with any ingredient or material so as to affect injuriously the quality or potency of such drug, with intent that the same may be sold in that state; and no person shall sell any drug so mixed, coloured, stained, or powdered . . ." (sec. 4). The penalty for such injurious admixture is a fine not exceeding £50 for a first offence; subsequent offences are misdemeanours, punishable by imprisonment with hard labour for a period not exceeding six months. No liability is, however, incurred if the accused person can show that he was unaware of the admixture, and could not, with reasonable diligence, have ascertained it (sec. 5).

No person shall sell, to the prejudice of the purchaser, any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding £20; but no offence shall be deemed to be committed under this section in the following cases:—(1) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof; (2) where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent; (3) where the food or drug is compounded . . . [and the provisions of the seventh and eighth sections are observed]; (4)

where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation" (sec. 6). As regards these exemptions, the *onus probandi* rests with the defendant (sec. 24). No person shall sell any compound, drug, or article of food which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20 (sec. 7); but no offence under this section is committed in respect of the sale of a drug or article of food mixed with an ingredient not injurious to health, if it is labelled as "mixed" at the time of sale (sec. 8).

"No person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it, so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration, under a penalty not exceeding £20" (sec. 9). In any prosecution under this Act, the defendant is to be discharged if he proves to the satisfaction of the Court (*a*) that he bought the article as being the same in nature, substance, and quality with that demanded by the purchaser, and with a written warranty to that effect; (*b*) that at the time of sale he had no reason to believe it to be otherwise; and (*c*) that he sold it in the same state as when he purchased it (sec. 25).

As an outcome of the report of a committee which inquired into the uses and abuses of preservatives and colouring matters in food, it is probable that this Act will be soon amended and strengthened in special reference to these points; the recommendations made have already been given on p. 168.

In order to carry out the provisions of this Act, in every district a competent person may be, and if required by the L.G.B. must be, appointed as public analyst (sec. 10). In the case of boroughs having a separate Court of Quarter Sessions, or a separate police force, this appointment is made by the town council: while for all other parts of the country it is made by the county council. All these appointments and re-appointments are subject to the approval of the L.G.B. When a public analyst is thus appointed, any purchaser of an article of food or drug within the district shall be entitled to have it analyzed for a fee of 10*s*. 6*d*., otherwise by another analyst, at such fee as he may require, and in either case to have a certificate of the result (sec 12). The M.O.H., the sanitary inspector, or any other officer charged by the S.A. with the execution of the Act, may procure samples of food and drugs, and submit them to the public analyst (sec. 13). The quantities of the samples purchased under sec. 13 should not be less, in the case of milk, than 1 pint; butter, $\frac{3}{4}$ of a lb.; lard, $\frac{3}{4}$ of a lb.; coffee, $\frac{3}{4}$ of a lb.; spirits, $\frac{3}{4}$ of a pint. Any person

purchasing an article for analysis shall, upon the completion of the purchase, forthwith notify to the seller his intention to have it analyzed by the public analyst; and shall offer to divide it into four parts, to be then and there separated, and each part to be marked and sealed or fastened up, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller. He must retain one of the four parts for future comparison, and deliver the third to the public analyst, and the fourth part he must send to the L.G.B. or B.A.

If the seller do not accept the offer of division, the analyst must divide the article into three parts, and seal up and deliver one of them to the purchaser (sec. 15). Samples may be sent to the analyst by post, in a registered letter, if his residence is two miles from that of the purchaser (sec. 16). Any person refusing to sell to an officer of the S.A. any article of food or drug on sale by retail, the price being tendered, and the quantity demanded not being greater than is reasonably requisite, is liable to a penalty not exceeding £10 (sec. 17). The certificate of the analyst must be in a prescribed form (sec. 18), and is sufficient evidence of the facts therein stated, unless the defendant requires the analyst to be called as a witness (sec. 21). The B.A. have the power to fix the limits of deficiency from the normal in the composition of milk, cream, butter, etc. The justices before whom a case is heard may, at the request of either party, cause any article of food or drug to be sent to the Commissioners of Inland Revenue for analysis by the chemists of their department at Somerset House (sec. 22).

Owing to certain defects in the Act of 1875, an Amendment Act was passed in 1879. This latter Act qualifies the earlier one by stating that "it shall be no defence to allege that the purchaser is not prejudiced by the sale of adulterated articles, on the ground that he bought it for analysis only; or to allege that the article in question, though defective in nature, *or* substance, *or* quality, was not defective in all three respects" (sec. 2). "The M.O.H., inspector, or constable charged with the execution of the Act, may procure, at the place of delivery, a sample of milk in course of delivery to the purchaser or consignee, in pursuance of any contract; and may submit the sample to the public analyst" (sec. 3). "The seller, or his representative, if he refuses to allow a sufficient sample to be taken, is liable to a penalty not exceeding £10" (sec. 4). "As regards spirits not adulterated otherwise than by admixture of water, it is a good defence to prove that the admixture has not reduced the spirit more than 25 degrees under proof for brandy, whisky, or rum; or 35 degrees under proof for gin" (sec. 6).

In order to prevent the fraudulent sale of margarine for butter, the Margarine Act, 1887, was passed. Sec. 3 of this Act defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, and with or without added colouring matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not. It shall be unlawful to manufacture, sell, or expose for sale, or import any margarine the fat of which contains more than 10 per cent. of butter fat (S.F.D.A., 1899, sec. 8). Every package or parcel of margarine must be so marked, in capital letters not less than a quarter of an inch square (sec. 6). All margarine factories must be registered with the S.A., by whom the public analyst of the district is appointed (sec. 9). Officers authorized to take samples under the Sale of Food and Drugs Act may take samples of butter (or substances purporting to be butter which are exposed for sale and not marked as margarine) without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (sec. 10). Any such substance not being marked as margarine is to be presumed to be exposed for sale as butter, so that there is a possible offence under both Acts. There is a saving clause similar to sec. 25 of the Sale of Food and Drugs Act, viz. that the vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter.

Under the S.F.D.A., 1899, any person who imports into the United Kingdom, any margarine or margarine-cheese, except in packages conspicuously marked; or adulterated or impoverished butter (other than margarine); or adulterated or impoverished milk or cream, except in packages or cans marked with a name or description indicating that the butter or milk or cream has been so treated; or condensed, separated, or skimmed milk, except in tins or other receptacles which bear a label whereon the words "Machine-skimmed Milk" or "Skimmed Milk," as the case may require, are printed in large and legible type; or any adulterated or impoverished food to which by Order in Council this section shall be applied, shall be liable, on summary conviction, for the first offence to a fine not exceeding £20, for the second offence to a fine not exceeding £50, and for any subsequent offence to a fine not exceeding £100.

The S.F.D.A., 1899, enacts that when any article of food or drug has been purchased from any person for test purposes, any prosecution under the Sale of Food and Drugs Act in respect to the sale shall not be instituted after the expiration of twenty-eight days (sec. 19), and a warranty or invoice shall not be available as

a defence to any proceedings unless the defendant has, within seven days after the service of the summons, sent to purchaser a copy of such warranty or invoice, with a written notice that he intends to rely on the warranty, and specifying the name and address of the person from whom he received it, and has also sent a like notice of his intention to such person (sec. 20).

Infectious Diseases.—The P.H.A., 1875, enacts that, upon the certificate of a M.O.H. or other medical practitioner that the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious disease, it is incumbent on the S.A. to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A daily penalty not exceeding 10*s.* is incurred by default, and the authority may do what is necessary and recover the costs, or may undertake the duty in the first instance, with the consent of the occupier, at their own cost (sec. 120). Under the I.D.P.A., 1890 and 1899, the above section is repealed, and the provisions so far modified that the S.A. may, after twenty-four hours' notice, proceed to carry out such disinfection or cleansing, unless within that time the owner or occupier informs the authority that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the M.O.H. In case of default, the S.A. may cause the necessary work to be done and recover the expenses. Power of entry between 10 a.m. and 6 p.m. is given for the purposes of this section (Infectious Diseases Prevention Act, 1890, secs. 5 and 17).

By sec. 121, P.H.A, 1875, the S.A. may destroy infected bedding, clothing, or other articles, and give compensation. By sec. 6 of the Act of 1890, the authority may, by a written notice, require, under a penalty of £10, any infected clothing or other articles to be delivered to their officers for disinfection. The S.A. must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

The P.H.A., 1875, further enacts that a S.A. may provide a disinfecting apparatus and disinfect free of charge (sec. 122); also provide an ambulance and pay expenses of conveyance to hospital of infected persons (sec. 123). Where a hospital is provided within convenient distance, a justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or is lodged in a room occupied by more than one family, or is on board any ship or vessel (sec. 124). The authority may make regulations for removing to any available hospital, and for keeping there as long

as necessary, any persons brought within their district by vessel, who are infected with a dangerous infectious disorder (sec. 125). It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder, but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (sec. 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected, but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (sec. 127). Any person who knowingly lets for hire any house or room in which any person has suffered from such disorder, without having it and its contents disinfected to the satisfaction of a medical practitioner, as testified by a certificate signed by him, is liable to a penalty not exceeding £20 (sec. 128). Any person letting or offering for hire any house or part of a house, who on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question, becomes liable to penalty or imprisonment (sec. 129).

The above provisions have been supplemented in districts by the I.D.P.A., 1890, by the following enactment in sec. 7 of that Act. It provides that any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disorder, (1) *must* have such house or room, and all articles therein liable to retain infection, disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; and (2) *must* give to the owner notice of the previous existence of such disease; and (3) *must not* knowingly make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having, within six weeks previously, been therein any person suffering from any infectious disease. Penalties of £10 are provided in each case. Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection; or in default a daily penalty of 40*s*. (sec. 13). In any district where these sections are in force, the

S.A. must give notice of their provisions to the occupier of any house in which they are aware there is a person suffering from any infectious disease (sec. 14).

The P.H.A., 1875, secs. 131 to 133, enacts that any S.A. may build or contract for the use of hospitals for their district, two or more authorities, if necessary, combining for this purpose. The S.A. may recover from a patient, who is not a pauper, the cost of his maintenance in such hospital; and may, with the sanction of the L.G.B., themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district. Further, the I.D.P.A., 1890, requires the same authorities to provide free temporary shelter with any necessary attendance, for the members of any family in which infectious disease has appeared, who have to leave their dwellings to allow of disinfection by the S.A. Any person suffering from infectious disease, and being an inmate of a hospital for infectious diseases, and who upon leaving would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a justice, be detained in hospital at the cost of the S.A. for any specified period, and such period may be extended as often as necessary (sec. 12, Act of 1890).

With a view to promote the establishment of infectious hospitals, a very important Act was passed in 1893, called the Isolation Hospitals Act, giving to county councils limited power to secure the provision of isolation hospitals in their county. It applies to England and Wales generally, but not to London, or to any county borough; other boroughs are also exempt, except by order of the L.G.B., if the population be less than 10,000, at the last census, or by consent of the corporation if the population be 10,000 or more. A *hospital district* under this Act may consist of one or more local areas; a "local area" being defined as including an urban or rural sanitary district, or any contributory place. This district is constituted by order of the county council. To put this Act in force, the county council may take the initiative by directing their M.O.H. to report as to the hospital requirements of any part of their county, and acting upon his report; but they may also be set in motion by a petition from any local authority, or from twenty-five ratepayers in any contributory place. The next step is for the county council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its local authority, if it has already, in the judgment of the county council, adequate accommodation; nor must a hospital district be formed for one local area only, or for one or more local areas within the

same rural sanitary district, without the consent of the S.A., unless the county council are satisfied that the S.A. are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital committee, consisting of local representatives, but if a grant be made out of county funds, the committee may consist wholly or in part of county councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorized by this Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also, subject to county council regulations, undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be in connection with the system of telegraphs (sec. 13).

The county council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

"Structural" and "establishment" expenses are borne by the several local rates of the constituent local areas, in proportions to be fixed by the county council's Order. The cost of conveying, removing, feeding, medicines, disinfecting, and all other things required for patients individually, are termed "patients' expenses." For ordinary non-pauper patients they are to be paid by the local authority out of the rates of the local area from which the patient came, but the guardians are responsible if poor-law relief has been given at or within fourteen days at the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, "special patients' expenses," on such terms as the committee may appoint (secs. 17 to 19).

The I.H.A., 1893, has been considerably amended by the I.H.A. of 1901. Hitherto there has been some doubt as to the extent of the power of a district council or joint board who had provided a hospital under the P.H.A., 1875, to transfer their hospital to the county council. These powers have now been clearly explained, and facilities for exercising them materially furnished by the new Act. Further, difficulties in the way of hospital committees hiring temporarily a hospital from a district council whilst they themselves were erecting a permanent hospital, and also as to transferring patients from one district to the hospital of other authorities in times of stress or epidemics, are removed. The new Act, sec. 5, also provides that upon an appeal against any Order including any area in a hospital district under subsec. 3 of sec. 8 of the Act of 1893, the L.G.B. may confirm, disallow, or modify the Order as they think fit. Sec. 6 of the new Act

now provides that the rural district council shall, to the exclusion of any other authority, be the local authority in the case where a contributory place consisting of a parish is concerned. Hitherto, under the Act of 1893, a county council could only be represented upon a hospital committee by members of their own body. This is altered by sec. 8 of the new Act, whereby the representatives of the county council upon a hospital committee may be members of the council or not.

It is, of course, of the greatest importance from a sanitary point of view that the dead bodies of persons who have died of infectious diseases should not remain unburied in such a manner as to endanger the health of the survivors. The P.H.A., 1875, sec. 142, provides that where the dead body of any one who has died of any infectious disease is retained in a room in which persons live and sleep, any justice may, on a certificate signed by a medical man, order the body to be removed by the S.A. to a mortuary, and direct the same to be buried within a time to be limited by the Order; unless the friends of the deceased undertake to so bury the body within the time specified, it is the duty of the relieving officer to bury such body at the expense of the poor-rate; but any expenses so incurred may be recovered in a summary manner from any person legally liable to pay the expenses of the burial. A penalty of £5 attaches to any person obstructing the execution of an order made under this section.

Further provisions in respect of this matter are contained in secs. 8 to 11 of the Act, the I.D.P.A., 1890, which enact that the body of a person who has died of any infectious disease must not, without a certificate from the M.O.H. or a registered medical practitioner, be retained for more than forty-eight hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling-place, sleeping-place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a justice may, upon the application of the M.O.H., order the body to be removed by the S.A. to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within the specified time, the relieving officer must do so. The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the M.O.H. or other medical practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died of an infectious disease must not be conveyed in any public conveyance, other than a hearse, without due warning to the owner or driver, who must forthwith provide for disinfection.

In cases where there is any suspicion that an epidemic of infectious disease has its origin in any milk supply of the district, the powers of a S.A. under the C.D. (Animals) A., 1886, should not be lost sight of (see p. 462). In addition to these provisions, sanitary authorities of districts have power to prohibit the supply of milk from suspected dairies (sec. 4, I.D.P.A., 1890). If the M.O.H. has reason to believe that the consumption of milk from any dairy, farm, cowshed, milk-store, milk-shop, or other place from which milk is supplied within or without his district, has caused or is likely to cause infectious disease to any person residing in the district, he may, if authorized by a justice having jurisdiction in the place where the dairy is situate, inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk, he must report to the S.A., forwarding also any report furnished to him by the veterinary surgeon. The local authority may then give not less than twenty-four hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If in their opinion he fails to show such cause, they may order accordingly, and must give notice of the facts to the S.A. and the county council of the district in which the dairy is situate, and also to the L.G.B. The order must be forthwith withdrawn on the S.A. or the M.O.H. being satisfied that the milk supply has been changed, or that the cause for infection has been removed. Penalties of £5, and if a continuing offence of 40*s*. a day, are provided for contravention of this section of the Act.

The relation of schools to infectious diseases, and the action of the S.A. in the matter, is of importance. By Article 88 of the Education Code, approved by the Lords of the Committee of Council on Education, a S.A. has alternative power with respect to elementary public schools: (*a*) to notify the managers that particular scholars be for a specified time excluded from attendance, or (*b*) to require the school to be closed for a specified time. Managers of schools, after complying with the requirements of a S.A., have the right of appeal to the Education Department, if they consider any notice to be unreasonable. A S.A. has no power in respect to Sunday schools, or other private schools; except in so far as these may contravene sect. 91 (5) (nuisance from overcrowding), or sec. 126 (exposure of infected person or thing), or other provision of the P.H.A., 1875, but usually the managers of such schools are only too ready to co-operate in efforts for securing the public health.

One of the most important and valuable aids to the various foregoing provisions has been the *compulsory notification of infectious diseases* under the Notification Act of 1889, and the Infectious Diseases (Notification) Extension Act, 1899. The diseases scheduled in this Act are—small pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus, enteric fever, relapsing fever, continued fever, and puerperal fever; but power is given to the S.A., with the sanction of the L.G.B., to include any other infectious disease, such as measles, rotheln, or whooping-cough. The above-named and scheduled diseases are those practically to which also the I.D.P.A., 1890, applies. Every medical practitioner attending on, or called in to visit, the patient shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the medical officer of health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering. The penalty for default is a fine not exceeding 40*s*. Under the same penalty, the householder is compelled to notify, but in a less formal manner. Though the system of notification is "dual" under the Act, it is so only in theory; as practically the householder's share in the notification is allowed to lapse, unless there is no doctor in attendance. The Act does not apply to Government buildings, such as barracks, nor to any "hospital" in which persons suffering from infectious disease are received; it applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation." The Act gives no power of compulsory removal of patients to hospital, nor even power of entry upon premises for the purpose of making inquiries.

Sec. 130, P H.A., 1875, enables the L.G.B. to make regulations for the treatment of persons affected with cholera or any other infectious disease, and by the P.H. Acts, 1896 and 1904, to make regulations for preventing the spread of such diseases as well on the seas, rivers, and waters of the United Kingdom, and on the high seas within 3 miles of the coast thereof, as on land, and may declare by what S.A. such regulations shall be enforced and executed. Cholera, plague, and yellow fever regulations have been issued under these Acts.

In addition to these regulations, the L.G.B. have power under sec. 134 of the same Act, whenever any part of England appears to be threatened with, or is affected by, any formidable infectious disease, to make, and from time to time alter or revoke, regulations for any of the following purposes, namely, for the speedy interment of the dead, for promotion of cleansing, ventilation, and

disinfection, and for guarding against the spread of disease; and may by order declare all or any of the regulations so made to be in force within the whole or any part of the district of any S.A., and to apply to any vessels whether on inland waters or on parts of the sea within the jurisdiction of the Lord High Admiral of the United Kingdom. The local authorities are required to do everything that is necessary to carry out these regulations.

For the Metropolis, the legislative enactments relating to infectious diseases are practically all contained in the P.H. (Lond.) A., 1891, secs. 55 to 87, as both the I.D.N.A., 1889 and 1899, and the I.D.P.A., 1890, are embodied in the London Act of 1891. There are, however, a few modifications necessitated by the fact that the whole of the Metropolis has been formed into one asylum district, under managers known as the Metropolitan Asylums Board, who, by the Metropolitan Poor Acts of 1867, 1871, and the Diseases Prevention (Metropolis) Act, 1883, provide asylums for the insane and infirm as well as hospitals for infectious diseases.

As regards notification in London, there is an important difference of procedure as compared with England and Wales, namely, that a copy of the certificate must be sent by the M.O.H. of a sanitary authority both to the Asylums Board and to the head teacher of the school attended by the patient (if a child), or by any child who is an inmate of the same house as the patient. Besides this, the different medical officers of health receive weekly a full and complete list from the Asylums Board of all notifications in the respective metropolitan districts.

The London County Council have power to extend the provisions of the Act as to the notification of infectious disease to diseases not specifically mentioned. The other general provisions as to disinfection, removal of infected persons or dead bodies, and burial of the infective dead, are similar to those already explained.

Power is also given to the L.G.B. by sec. 13 of the L.C.C. (G.P.) A., 1890, to assign to the county council any duties and powers under epidemic regulations made by them in pursuance of sec. 134, P.H.A., 1875, as they deem desirable. In extension of the same, they may substitute the London County Council for any local authority, on whose default the council have power to proceed and act under the London Public Health Act of 1891.

APPENDIX.

MEASURES OF LENGTH.

THE **Standard Metre** is $\frac{443296}{864000}$ of the distance, at the temperature of 16·3° C., between the ends of a certain bar, called the "Toise of Peru," kept in the French Archives, and is approximately the ten-millionth part of the distance from one of the earth's poles to the Equator, at the meridian of Paris. This measure, and those founded on it, is lawful in this country, and a copy of the standard metre is kept in the Exchequer Office at Westminster.

The English **Standard Yard** is the distance, at the temperature of 62° F., between two marks on a certain bar which is kept in the office of the Exchequer.

The relative values of the Metric and English measures of length can be gathered from the following table:

	Metres.	Inches.	Feet.	Yards.	Miles.
Kilometre . .	1000		–		0·6214
Hectometre . .	100		–	—	—
Decametre . .	10	—			—
Metre . . .	1	39·37	3·28	1·0936	—
Decimetre . .	0·1			-	—
Centimetre . .	0·01		—	—	
Millimetre . .	0·001	0·03937			

MEASURES OF AREA.

	Square metres.	British measures of area	
Square Kilometre	1000000	0·3861	sq. mile.
,, Hectometre, or Hectare	10000	2·4711	acres.
,, Decametre, or Are . .	100	119·6	sq. yards.
,, **Metre**	1	10·764	sq. feet.
,, Decimetre.	0·01	15·5	sq. inches.
,, Centimetre	0·0001	0·155	,,
,, Millimetre	0·000001	0·00155	,,

SOLID MEASURES.

1 Cubic Decametre, or Kilostere, equals		35,316·5	cubic feet.
,, **Metre**, or **Stere**,	,,	35·3	,,
,, Decimetre, or Millistere,	,,	61·025	cubic inches.
,, Centimetre	,,	0·061	,,
,, Millimetre	,,	0·000061	,,

MEASURES OF WEIGHT.

The metric **Standard Kilogramme** is the weight, at the temperature of the maximum density of water (4° C.), and under the atmospheric pressure of 760 millimetres of mercury, in the latitude of Paris, of a certain piece of platinum which is kept in the French Archives. A copy of this standard kilogramme is kept in our Exchequer Office. The kilogramme was at first intended to be the weight of one cubic decimetre of pure water at its maximum density, but it is in actual fact slightly greater.

The English **Standard Pound Avoirdupois** is the weight, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury, in the latitude of London, and at or near the level of the sea, of a certain piece of platinum, which is kept in the Exchequer Office at Westminster.

The relative values of the Metric and English weights is shown in the following table :-

	Grammes.	Grains.	Avoir. ozs.	Avoir. lbs.
Kilogramme . .	**1000**	**15432**	**35·3**	**2·2**
Hectogramme . .	100			– –
Decagramme . .	10	–	—	—
Gramme. . . .	1	15·432	0·0353	0·0022
Decigramme . .	0·1	–	-	-
Centigramme . .	0·01			
Milligramme . .	0·001	0·0154		

MEASURES OF CAPACITY.

The metric **Standard Litre** is the volume of a kilogramme of pure water at its temperature of maximum density (4° C.) and under the atmospheric pressure of 760 millimetres of mercury. It was originally intended to be a cubic decimetre, but is actually a little greater. Under the above-mentioned conditions, a litre of pure water weighs one kilogramme.

The English **Standard Gallon** is the volume of 10 lbs. avoirdupois of pure water, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury.

The relative values of the Metric and English measures of capacity is shown in the following table :-

	Cubic centimetres.	Fluid ozs.	Pints.	Gallons.	Cubic ins.
Kilolitre . . .	1000000	—		–	– –
Hectolitre . .	100000	—	-		-
Decalitre . .	10000	—	—	-	—
Litre	**1000**	**35·3**	**1·76**	**0·22**	**61·027**
Decilitre . . .	100	–	—	—	—
Centilitre . .	10	- -	—	—	—
Millilitre . . .	1	—	—	—	—

TABLE OF FACTORS FOR CALCULATING EQUIVALENTS OF WEIGHT, VOLUME, LENGTH, ETC.

To convert	grammes . .	to pounds,	multiply by	0·0022
,,	,, . .	to grains,	,,	15·432
,,	,, . .	to ounces,	,,	0·0353
,,	grains . . .	to grammes,	,,	0·0648
,,	ounces . . .	to ,,	,,	28·349
,,	pounds . . .	to ,,	,,	453·715
,,	kilogrammes .	to pounds,	,,	2·204
,,	,, .	to ounces,	,,	35·3
,,	litres . . .	to gallons,	,,	0·22
,,	,, . . .	to fluid ounces,	,,	35·3
,,	,, . . .	to pints,	,,	1·76
,,	,, . . .	to cubic feet,	,,	0·0354
,,	,, . . .	to cubic inches,	,,	61·027
,,	gallons . . .	to cubic feet,	,,	0·1605
,,	,, . . .	to litres,	,,	4·5371
,,	pints . . .	to ,,	,,	0·5679
,,	,, . . .	to cubic centimetres,	,,	568·1818
,,	,, . . .	to cubic inches,	,,	34·67
,,	cubic metres .	to gallons,	,,	220·4
,,	,, .	to pints,	,,	1763·2
,,	,, .	to fluid ounces,	,,	35264·0
,,	,, .	to cubic centimetres,	,,	1000000·0
,,	cubic feet . .	to cubic metres,	,,	0·0283
,,	,, . .	to litres,	,,	28·318
,,	,, . .	to gallons,	,,	6·2322
,,	fluid ounces .	to cubic inches,	,,	1·7299
,,	,, .	to cubic centimetres,	,,	28·35
,,	square feet . .	to square metres,	,,	0·0929
,,	,, . .	to square yards,	,,	0·111
,,	square metres .	to square feet,	,,	10·7641
,,	inches . . .	to metres,	,,	0·0254
,,	,, . . .	to millimetres,	,,	25·4
,,	metres . . .	to inches,	,,	39·37
,,	,, . . .	to feet,	,,	3·28
,,	feet	to miles,	,,	0·000187
,,	yards . . .	to ,,	,,	0·00057
,,	,, . . .	to centimetres,	,,	91·44
,,	centimetres .	to inches,	,,	0·3937
,,	millimetres .	to ,,	,,	0·03937
,,	kilometres . .	to miles,	,,	1·6
,,	square kilometres	to square miles,	,,	2·5899
,,	hectares . .	to acres,	,,	0·4046

THE CHEMICAL SYMBOLS AND ATOMIC WEIGHTS OF ELEMENTARY BODIES.

Names of elements.	Chemical symbols.	Atomic weights.	Names of elements.	Chemical symbols.	Atomic weights.
Aluminium	Al	27·5	Nitrogen	N	14·0
Antimony	Sb	120·0	Oxygen	O	16·0
Arsenic	As	75·0	Palladium	Pd	105·7
Barium	Ba	137·0	Phosphorus	P	31·0
Bromine	Br	80·0	Platinum	Pt	197·2
Cadmium	Cd	112·0	Potassium	K	39·0
Calcium	Ca	40·0	Rubidium	Rb	85·3
Carbon	C	12·0	Selenium	Se	78·8
Chlorine	Cl	35·5	Silicon	Si	28·0
Chromium	Cr	52·5	Silver	Ag	108·0
Cobalt	Co	59·0	Sodium	Na	23·0
Copper	Cu	63·2	Strontium	Sr	87·4
Fluorine	F	19·0	Sulphur	S	32·0
Gold	Au	196·2	Tantalum	Ta	182·0
Hydrogen	H	1·0	Tellurium	Te	125·0
Iodine	I	126·6	Thallium	Tl	203·7
Iridium	Ir	192·7	Thorium	Th	231·5
Iron	Fe	56·0	Tin	Sn	118·0
Lead	Pb	206·5	Titanium	Ti	48·0
Lithium	Li	7·0	Tungsten	W	184·0
Magnesium	Mg	24·0	Uranium	U	240·0
Manganese	Mn	55·0	Vanadium	V	51·3
Mercury	Hg	200·0	Yttrium	Y	88·0
Molybdenum	Mo	95·5	Zinc	Zn	65·0
Nickel	Ni	59·0	Zirconium	Zr	89·4

PREPARATION OF CULTURE MEDIA.

A variety of culture media have been alluded to in the text, particularly in the section which deals with the bacteriological examination of a water sample. The manner of preparing but one has been given in detail—namely, the bile-salt glucose broth used in MacConkey's method. Details as to some other media in common use are given below.

Nutrient Broth.—One pound of meat, free from fat, must be minced finely, then infused in a litre of cold distilled water, and allowed to stand in a cold place for twenty-four hours. The whole mass is then strained through a cloth, and distilled water added to the filtrate so as to make up the volume of fluid to one litre. Ten grammes of peptone and five grammes of common salt are now added to the litre of fluid, which is then boiled in the steam sterilizer for one hour at 100° C. Owing to the presence of acid phosphates of potassium and sodium, weak acids of the glycolic series and organic compounds in which the acid character predominates, this meat extract will be more or less acid. It will always react acid to phenolphthalein, but occasionally reacts neutral or even alkaline to litmus. Further, if exactly neutral to litmus, it will be found to react acid to phenolphthalein. The main reason for this is due to the fact that litmus is insensitive to many weak organic acids, the presence of which is

readily indicated by phenolphthalein. Estimate the reaction of the medium by placing 25 c.c. of it into a clean beaker, running in 0·5 c.c. of phenolphthalein solution, immersing the beaker in a water-bath, and raising to the boil. Now cautiously run in to the medium in the beaker, standing in the water-bath at the boil, some $\frac{N}{10}$NaOH solution, until the end point is reached as indicated by the development of a faint pink tinge. Note the amount of deci-normal soda solution used. It is convenient to use broth media standardized to +10, the symbol + meaning acid and − meaning alkaline, in both cases to phenolphthalein as indicator. Briefly, the method of standardizing a litre of broth or other medium to +10 consists in subtracting 10 from the initial *titre* of the medium mass; the remainder indicates the number of cubic centimetres of normal soda solution that must be added to the medium, per litre, to render the reaction +10. Say, 25 c.c. of the medium have required the addition of 5·65 c.c. $\frac{N}{10}$NaOH solution to neutralize it, and therefore 1000 c.c. will require 226 c.c. or 22·6 c.c. of $\frac{N}{1}$NaOH solution. The initial *titre*, then, of this medium will be +22·6, and as such requires the addition of (22·6 − 10)12·6 c.c. of normal NaOH per litre to leave its finished reaction at +10. To be strictly accurate, allowance must be made for the volume of medium used in the titrations, and remembrance made that the remainder of medium to be neutralized does not now measure a full litre. Say, three titrations were made, each with 25 c.c., then the original bulk of the medium will be but 925 c.c., requiring but 11·65 c.c. of normal NaOH to make it +10.

Having brought the medium to the required reaction, heat again for half an hour at 100° C., to complete the precipitation of phosphates. Filter through Swedish filter-paper into sterile tubes (10 c.c. in each). Plug the tubes with cotton wool, and then sterilize these in the steamer on three successive days for twenty minutes.

Glucose and Lactose Broth.—These are simply the above ordinary broths containing 1 or 2 per cent. of either grape or milk sugar. The steps in the preparation are the same as those just described.

Nutrient Gelatine.—This is made by adding 10 to 15 per cent. of best gold-label gelatine, cut into small pieces, to ordinary broth prepared as above, and then melting it by steaming at 100° C. for one hour. Estimate the reaction of the medium mass, as explained for broth, then add sufficient normal soda solution to render the reaction of the calculated bulk of medium +10. Replace in the steamer, and keep at 100° C. for twenty minutes, to precipitate all the phosphates. Allow to cool to 60° C. Add the whites of two eggs for each litre of medium, replace in steamer at 100° C. for half an hour; then filter through Chardin paper into sterile tubes. Sterilize these at 100° C for twenty minutes on each of three consecutive days.

Glucose and Lactose Gelatine are made in the same way, adding 1 to 2 per cent. of the respective sugars.

Nutrient Agar-Agar.—Add 15 grms. of agar, cut into very fine fragments, to a litre of ordinary broth, prepared as explained. Dissolve by heating at 100° C. for an hour and a half. Estimate the reaction of the medium mass as explained under the head of "Broth;" then add sufficient normal soda solution to render the reaction of the calculated bulk of the medium +10. Replace in the steamer for twenty minutes to complete the precipitation of phosphates. Allow the medium to cool to 60° C., add whites of two eggs, replace in steamer, and keep at 100° C. for half an hour. Now filter through Chardin paper, by the aid of a hot-water funnel, into sterile tubes. Sterilize these in the steamer at 100° C. for half an hour on each of three successive days.

Glycerine Agar is made in the same way, 6 per cent. of glycerine being added after filtration.

Glucose and Lactose Agar are made as under ordinary agar, 2 per cent. of the respective sugars being added, as the case may be. If required to be tinted with neutral red, 2 per cent. of a half per cent. solution of neutral red is added before filtration.

Peptone Solution.—One to 2 per cent. of Witte's peptone with 0·5 per cent. of common salt are dissolved in distilled water by heating. The fluid is then filtered, placed in tubes, and sterilized. In this medium, cholera vibrios grow with great rapidity. It is also much used for testing the formation of indol by different bacteria.

Glucose Peptone Solution.—Made by dissolving, by means of heat, 1 grm. of glucose, 1 grm. of peptone, and ½ grm. of salt in 100 c.c. of distilled water. This is filtered, rendered neutral to litmus, placed in steamer at 100° C. for half an hour, then tubed into test-tubes containing inverted fermentation tubes, and sterilized for twenty minutes at 100° C. on three successive days.

Lactose Peptone Solution.—Prepared as the foregoing, substituting lactose for the glucose.

Sucrose Peptone Solution.—Prepared as the foregoing, substituting pure cane-sugar for the glucose or lactose.

Mannite Peptone Solution.—Prepared as the foregoing, substituting the alcohol mannite for one or other of the sugars.

Proskauer and Capaldi's Media.—The No. I. medium has the following composition: Asparagin and mannite of each 0·2 per cent.; potassium monophosphate, 0·2 per cent.; sodium chloride and calcium chloride of each 0·02 per cent.; and of magnesium sulphate, 0·01 per cent. The reagents are dissolved in distilled water, sterilized for an hour at 100° C. The medium is then rendered neutral to litmus by the addition of sufficient normal caustic soda solution. Sufficient litmus solution is added to give the medium a purple tint. It is now tubed and sterilized in the usual way for twenty minutes at 100° C. on three successive days.

The No. II. medium contains 2 per cent. of Witte's peptone and 0·1 per cent. of mannite dissolved in distilled water. Sterilized at 100 C. for an hour. This will be now found to be alkaline; it is next carefully rendered neutral to litmus by the addition of a saturated solution of citric acid. Litmus solution is added to give it a deep red colour. It is now tubed and sterilized in the usual way for twenty minutes at 100° C. on three successive days. These media are of great value in the differential diagnosis between the *B. coli* and the *B. typhosus*.

Milk.—Fresh milk and free from any preservative is steamed for half an hour at 100 C., and then placed in a cool place overnight for separation of cream. The milk is then siphoned off from beneath the cream, and placed in sterile tubes; if necessary, sufficient litmus solution is added to give it a purple tinge. The tubes are plugged, and then sterilized at 100° C. for twenty minutes on each of three successive days.

Potato Medium.—A large potato is well washed and scrubbed with a brush. A cylinder is then bored from its interior, and cut obliquely. The peel from the ends is cut off, and the wedges so obtained allowed to soak overnight in cold water to get rid of any excess of starch. Each wedge of potato is then placed in a test-tube, previously fitted with a pad of cotton wool at the bottom, and filled for about ½ inch in depth with distilled water. The tube is now plugged with cotton wool, and sterilized at 100° C. for twenty minutes on three successive days.

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THE END.

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